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ESSAYS ON U.S. BEEF MARKETS

Elham Darbandi
University of Kentucky, elham.darbandi2@gmail.com
Author ORCID Identifier:
https://orcid.org/0000-0003-0737-9335
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Elham Darbandi, Student

Dr. Sayed Saghaian, Major Professor

Dr. Carl Dillon, Director of Graduate Studies

ESSAYS ON U.S. BEEF MARKETS

DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Agriculture, Food and Environment at the University of Kentucky

By
Elham Darbandi
Lexington, Kentucky

Director: Dr. Sayed Saghaian, Professor of Agricultural Economics

Lexington, Kentucky
2017

ABSTRACT OF DISSERTATION

ESSAYS ON U.S. BEEF MARKETS

This dissertation includes three essays on U.S. beef market. Each essay has looked at this market from a different point of view. The first essay investigates the price adjustment along the different levels of this market. The second essay discusses the impact of food safety incidents on export levels in this market. The third essay considers the environmental loading of U.S. beef market. A summary of each article is as follows.

The first essay (chapter 2) analyzes price adjustment of the U.S. beef sector with a focus on the Great Recession. To this purpose, the Vector Error Correction Model (VECM) and historical decomposition graphs are applied to monthly data. The results indicate that retail prices have lower speeds of adjustment than wholesale prices. Also, the magnitude of price adjustment in the presence of the Great Recession, as an exogenous shock, is different for each level of the U.S. beef market. It is concluded that, with respect to both the speed and magnitude of the price adjustment, the U.S. beef sector has an asymmetric price adjustment, pointing to the inefficiency of the U.S. beef supply chain. These results have welfare implications for U.S. beef consumers and producers.

The primary objective of the second essay (chapter 3) is to quantify the impact of consumer awareness about beef safety on U.S. beef exports. To do that, an index is used to reflect consumer's awareness about beef safety based on the publicized reports in the media. Quarterly panel data is applied to the top importing countries, Japan, South Korea, Mexico, and Canada for the period 2000-2016. Applying the gravity model, results show that a 0.8% reduction in U.S. beef exports arose from the foodborne-disease news. In addition, using impulse response functions derived from panel vector autoregressive (Panel VAR) estimation, results show that the negative impact of a shock in food safety news intensified after three quarters, and then diminished slowly over time. In order to regain consumers' confidence and to compensate for the economic loss arising from a foodborne outbreak, bilateral cooperation among trade partners seems necessary. Investing in any scheme that minimizes the impact of food safety events, such as disease eradication programs, traceability systems, quality labeling, and third party certification that conveys the safety message to consumers is suggested.

The third essay (chapter 4) has two purposes. First, it quantifies the environmental loading of U.S. beef sector by calculating emission levels over the period 1970-2014. Beef cattle is one of the most emission-intensive sectors, which is responsible for 35% to 54% of total GHGs from livestock. Following International Panel on Climate Change (IPCC) guideline, this study identifies three sources of emissions, including enteric fermentation, manure management, and manure left on pastures. Second, it provides an understanding of consumption-environmental connection related to the beef industry using time series techniques. Finally, it is suggested that providing information to the public regarding livestock and climate change relationship would be beneficial. This knowledge might help to avoid the catastrophic consequences of climate change in the future.

KEYWORDS: Beef Safety, Climate Change, Consumer Awareness, Price Transmission, U.S. Beef Market

Elham Darbandi

November 15, 2017

ESSAYS ON U.S. BEEF MARKETS

By

Elham Darbandi

Dr. Sayed Saghaian

Director of Dissertation

Dr. Carl Dillon

Director of Graduate Studies

Date

To my mother and father:

I would not have been able to complete this degree without your patience for several years of being far from me. I will be thankful forever.

To my husband, Milad:

I learned from you to value my research and the process of learning. Without your help to take care of our baby when I was working on my dissertation, it was impossible to complete this work.

And to Rahdeen:

your entrance into this world made my life a blessing.

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I would like to extend my greatest appreciation to my advisor, professor Sayed Saghaian, who contributed greatly to this dissertation. I am grateful for his help during my PhD program, his support, and editorial assistance. Next, I wish to thank my PhD advisory committee: Dr. Kenneth Burdine, Dr. Yuqing Zheng, and Dr. Eric Vanzant. Each individual provided insights that guided my research objectives.

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1.1. Overview of U.S. Beef Market

The United State is the largest beef producer in the world. In terms of cattle and calf inventory, the United State is among the top four countries in the world, behind India, Brazil and China (FAO, 2016; Lowe and Cereffi 2009), also it is dominant in creating consumer value from the cattle market. Consumer value is related to the satisfaction of consumers from a purchase and is a marketing concept (Holbrook, 1999).
The following is a summary of the U.S. beef sector using the value chain concept. Michael Porter first introduced the idea of value chain in 1985 based on business management. Value chain is the idea of considering an organization as a system, while each system consists of sub-systems that involves ownership and utilization of inputs and outputs. In other words, value chain is a system of activities that a firm carries out to create value for its consumer by delivering a valuable product or service (Porter, 1985). Therefore, to explain the beef industry as a whole system we explain each step briefly, including cow-calf operation, the stocker operation, the feedlot, the beef packing and processing, and finally the retail level.

1.2. Overview of U.S. Beef Farming

Terminology of beef and cattle industry consists of cow, bull, calf, steer and heifer. Each term has a different meaning explained as follows. The term cow refers to a mature female bovine. Bull refers to a mature male. The term calf refers to young cattle of either gender. The term of calf is typically used during weaning time. Steer is a castrated male bovine. Heifer is used for young female animal prior to first calf (Delbridge, 1991). Also weaned calves, feeder cattle, and fed cattle respectively refer to calves after being removed from cow, cattle ready to be placed on feed in feedlots and cattle ready for harvest. Finally, boxed beef is a term that we use to refer to beef processed and ready to be sold at the retail level. Figure 1-1 shows the main stockholder in the U.S. beef system.

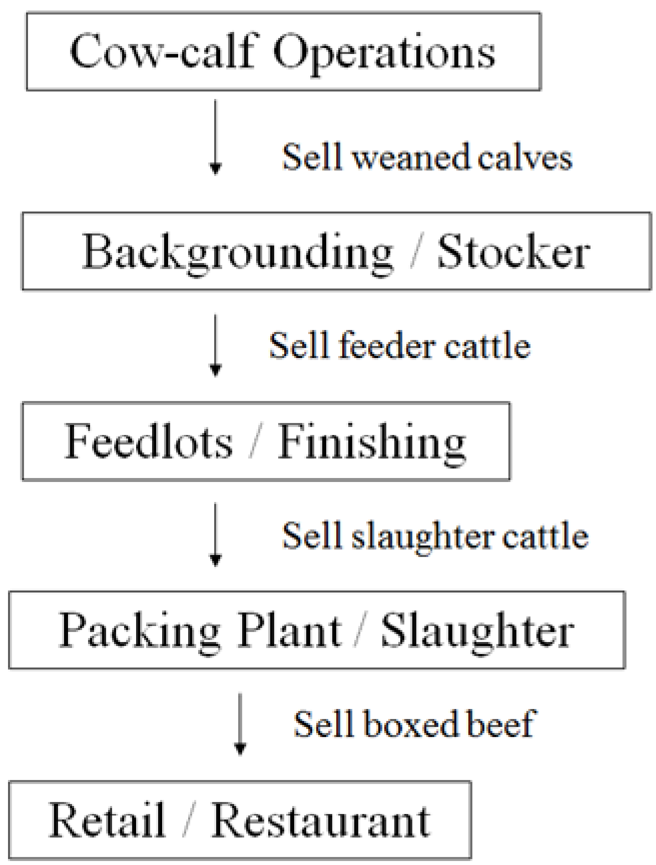

Figure 1-1: Schematic View of U.S. Beef System

From the above figure, the beginning phase in beef production process is cow-calf operation. The average size of the U.S. beef breeding herd is around 45 cows. From total beef operations, 9 percent have 100 or more cows (Exchange, 2006). Cattle production is an important industry in the United States, accounting $78.2 billion in cash receipt. Cow-calf operation is one of the two main sectors within the U.S. beef/cattle industries. Other important sector is cattle feeding (USDA-ERS, 2016). Calves are weaned from the cows when they are six to eight months of age and are their weight is between 500 to 600 pounds. At the stocker/ background stage, weaned calves are nourished by summer grass, winter wheat and harvested roughage. This stage may take from six to ten months until the animal weight is about 600 to 800 pounds. It should be mentioned that those animals that are heavy enough after weaning might directly be sent to the feedlot stage. But most of the calves need stocker operation as an intermediate stage. More information about the beef industry is provided in the next sections.

1.3. Primary Production

As the largest beef producer in the world, the United State is a leader in producing high quality and grain fed beef for domestic and world markets. Total beef supply in the U.S. during 2015 was 23,760 million pounds (USDA-ERS, 2016). Researchers applied pipeline approach to estimate the number of a commodity at a specific time in future regarding observation at different stages of the production process. Pipeline technique is common in livestock industry and the assumption is what goes into the pipeline must finally come out, accounting for loss, death and export. Therefore, livestock come into production pipeline at farm level and exist at supermarkets (Exchange, 2006).

We need to consider the effect of imports and exports into account at the pipeline approach. This information is required to estimate the total slaughter number. It is worthwhile to mention that slaughter and production numbers are only affected by importing live animals. It is while total supply number is affected by import of beef (Exchange, 2006). 49 percent of U.S. red meat in 2015 is produced by Texas, Kansas, Iowa and Nebraska (USDA-NASS, 2015). Annual commercial data for the production of beef and red meat during 2010-2015 is reflected in table 1-1.

Table 1-1: Red Meat and Beef Production in Commercial Plants (Billion Pounds)

Year	Red Meat Production	Beef Production
2010	49.0	26.3
2011	49.2	26.2
2012	49.4	25.9
2013	49.2	25.7
2014	47.3	24.3
2015	48.4	23.7

Source: USDA-NASS, different years
Note: Red meat includes beef, veal, pork, lamb and mutton

According to the data in Table 1-1, production of beef has decreased by 6 percent in 2014 from the previous year. However, red meat production has increased in 2015. Also a comparison between beef production and cattle inventory is represented in Figure 1-2.

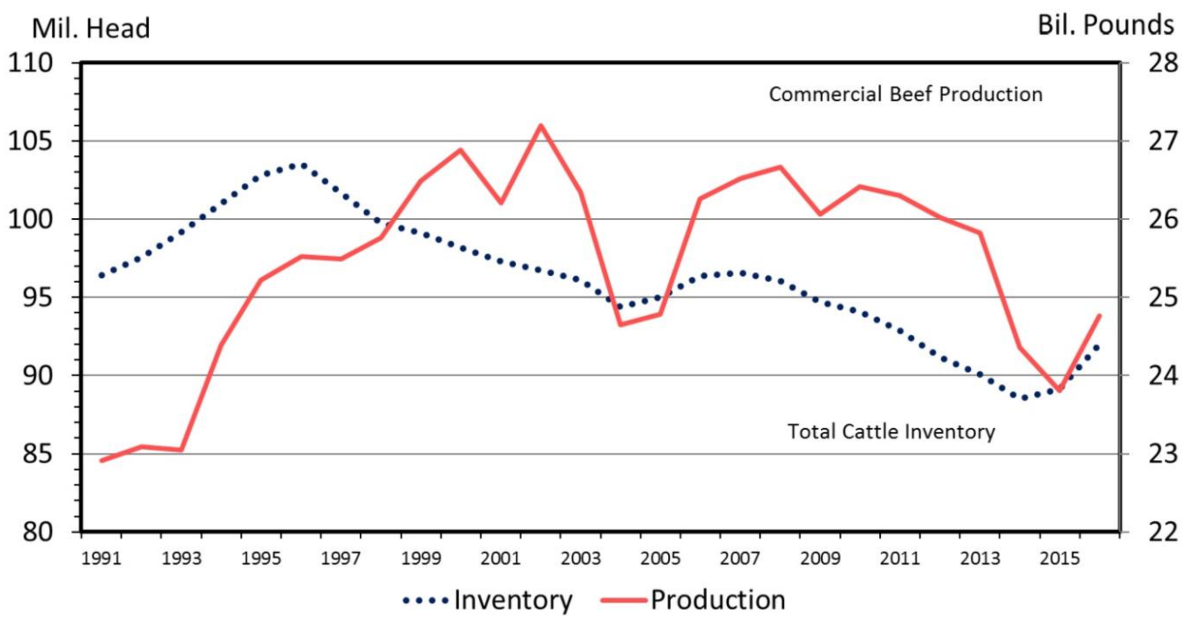

Figure 1-2: Beef Production vs. Cattle Inventory, Inventory on January 1th
Source: Adopted from Livestock Marketing Information Center (LMIC)

What we can learn from the above figure is that total cattle inventory is decreasing over time, while beef production has a different pattern. Regarding the sharp reduction in

2003-2005, and after that in 2013, beef production represents a variant trend during 1991-2015.

Based on the 2012 Census of Agriculture by USDA, cattle industry comprises 19 percent of total U.S. agriculture sales. Sales of cattle and calves reached $76.4 billion in 2012 that represent 25 percent increase since 2007, when the previous agriculture census was conducted. Also, sales of beef cattle reached $29.6 billion that comprises 7 percent of total U.S. agriculture sales in 2012. In the period 2007-2012, we had a 19 percent increase in beef cattle, it is while the number of firms with beef cows and inventory declined by 5 percent and 12 percent, respectively (Table 1-2).

Table 1-2: U.S. Beef Cattle Farming (2007-2012)

Variable	2007	2012	Change (Percent)
Sales ($ billions)	24.9	29.6	+18.8
Number of Firms	764,984	727,906	- 4.8
End-of- Year Inventory (millions)	32.8	29.0	- 11.8

Source: USDA- NASS, 2012 Census of Agriculture

Despite the fact that all states have cattle production, 73 percent of cattle and calves sales are related to the top ten states including, Texas, Kansas, Nebraska, Iowa, Colorado, Oklahoma, California, South Dakota, Missouri, Idaho. Table 1-3 represents the share of these states in cattle and calves sale.

Table 1-3: Top States in Cattle and Calves Sales ($ billions)

Texas	13.0
Kansas	10.2
Nebraska	10.1
Iowa	4.5
Colorado	4.3
Oklahoma	3.4
California	3.3
South Dakota	3.0
Missouri	2.0
Idaho	1.8

Source: USDA-NASS, 2012 Census of Agriculture

From table 1-3 and 1-4, we can see Texas has the highest rank in both cattle and calves sales and in beef cows inventory. However, from the point of beef cows' sales it is behind the Nebraska. It should be mentioned that there are some states that only have a good ranking in beef cows' inventory and not in beef sales. We can refer to Kentucky as an example (Table 1-4).

Table 1-4: Top States in Beef Cows Sales and Inventory

States	Beef Cows Sales ($ billions)	States	Inventory ($ millions)
Nebraska	3.7	Texas	4.3
Texas	3.3	Nebraska	1.7
South Dakota	2.2	Missouri	1.7
Kansas	1.8	Oklahoma	1.7
Oklahoma	1.6	South Dakota	1.6
Montana	1.5	Montana	1.4
Iowa	1.5	Kansas	1.3
Missouri	1.4	Kentucky	1.0
Colorado	1.1	Florida	1.0
North Dakota	0.9	Iowa	0.9
Total	19.0	Total	16.6

Source: USDA NASS, 2012 Census of Agriculture

Figure 1-3 can provide a visual explanation for geographic distribution of top states in beef cows' inventory. The data is related to 2016.

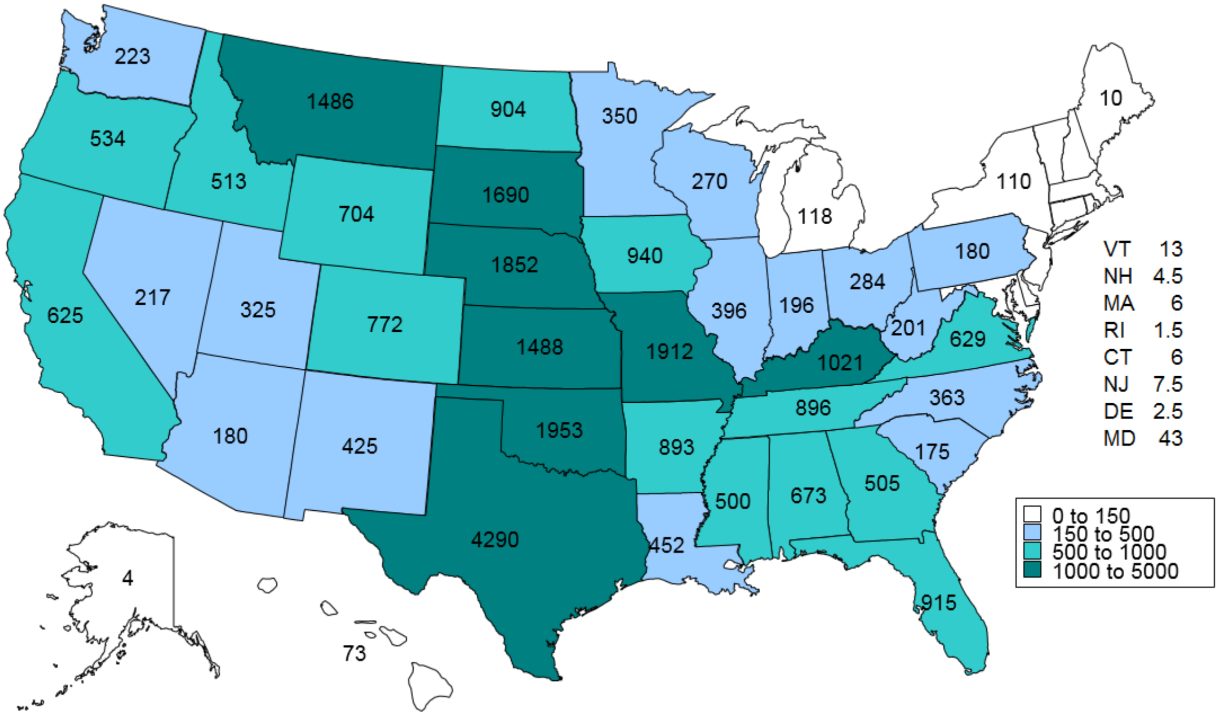

Figure 1-3: Beef Cows That Calved. January 1, 2016 (1000 Head)

Source: Livestock Marketing Information Center (LMIC)

As we can see, top ten states in beef cows inventory are including, Texas, Oklahoma, Missouri, Nebraska, South Dakota, Kansas, Montana, Kentucky, Florida and Iowa in 2016, with a little change from 2012.

1.4. Packing and Processing Units

As we mentioned earlier, the feedlot stage is one of the two important stages within the beef industry. Operations continue to feed the animal until it has the desired optimum weight, fat and muscling. That is time when the animal is called “finished” and is ready to send for slaughter. Packers, who buy cattle after the feedlot stage, have two main sources of income. One comes from sales of meat, another source is from sales of the hide and offal. In the recent years, packers sell more case-ready beef that means the meat has been cut into retail cuts. Retailers, who buy from packers, directly put case-ready beef in meat section to sell. It is while, before packers just divided the slaughter animals into major cuts and retailers had to do the future fabrication before final sale (Exchange, 2006). We can conclude that more value added is creating now at the packing and processing units by selling case-ready beef to retailers. From a slaughtered animal, 65 percent of the meat is processed into steaks and 45 percent is allocated to ground beef and stew meat.

1.5. Retail Level

Beef is the most consumed red meat in the United States. The average per capita consumption for beef was 61.1 and 60.8 pounds in 2014 and 2015, respectively**.** In the United States, there are three kinds of beef available to consumers that vary in their quality levels. The grades are decided based on measurements of beef tenderness, juiciness, and flavor by USDA meat graders' subjective assessments, and by electronic instruments. Prime, choice, and select are the three quality grades awarded. Most of the graded beef sold in the supermarkets is either USDA Choice or USDA Select (USDA-NASS, 2012; Surathkal, Chung, and Han, 2014). The wholesale cutout beef data from USDA's Agricultural Marketing Service (USDA-AMS, 2016) show that the share of Choice, Select, and Prime in total graded and branded beef products is about 47%, 36%, and 1%, respectively. Prime beef is considered as the highest quality grade based on marbling and is generally sold in restaurants and hotels rather than supermarkets. The Choice grade is considered to be superior in quality to the Select grade (Surathkal, Chung, and Han, 2014).

1.6. Beef Trade

Although the U.S. is the largest exporter of agricultural products in the world, it is a net importer of beef and purchase lower value and grass-fed beef for processing purposes, mainly as ground beef (USDA-ERS, 2016). Figure 1-4 shows beef import and export trend on an annual basis. It is evident, beef exports and cattle import show widely variation. The sharp drop in beef export after 2003 is related to the discovery of Bovine Spongiform Encephalopathy (BSE), known as “mad cow disease” in U.S. cattle. Many countries imposed restriction against importing U.S. beef and cattle (Exchange, 2006) that caused an interrupt in the growth of U.S. beef export. Gradually, the growth of beef export was retrieved and reached the above pre-BSE level by 2011. (USDA-ERS, 2016). In other words, the effect of BSE shock on the beef export was disappeared in around seven years by a 17-percent annual growth rate in export.

It is worthwhile to mention that 11 percent of domestic production in 2011 was dedicated to export while this share was 9 percent in 2003, before the BSE event. Also, since the beef has the highest price among other red meat, beef has been the top U.S. meat export in terms of export value for several years (USDA-ERS, 2016).

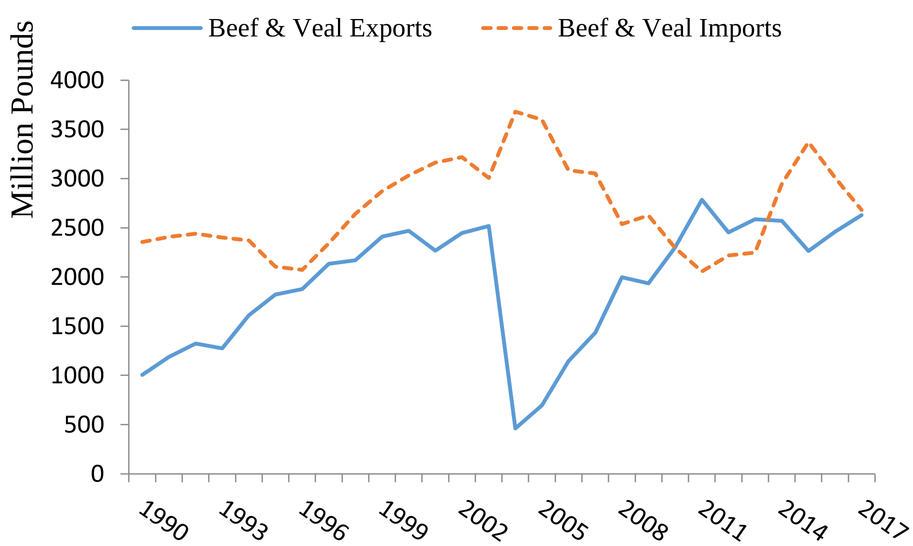

Figure 1-4: U.S. Beef Trade during 1990-2017
Note: Data related to 2016-2017 are forecasted data by USDA.
Data Source: USDA, Economic Research Service, Livestock and Meat Trade Data.

1.7. Cattle Trade

Despite having the largest fed-cattle industry in the world, United States is a net importer of cattle. Mexico and Canada are two main sources of cattle to the U.S. market, part of it is because of their close distance to the United States. There is a difference between these two suppliers in terms of purpose of import. About three-fourth of cattle imported from Canada are considered for slaughtering promptly. It is while, Cattle from Mexico are considered for stocker or feeder operations in the United States, and usually have lighter weight.

It can be readily seen in Figure 1-5 that there is a variation in import. Part of it is because of BSE case in Canada discovered in May 2003. That resulted in banning import from Canada. Later in July 2005, United States resumed imports from Canada but restricted it to animals less than 30 month of age. Also, in July 2006 another discovery of BSE was announced by Canada and it led into limitation of import from Canada. In November 2007, United States passed a rule and narrowed the import of live animals over 30 months of age to countries identified as "minimal-risk-country". Canada is the only country that has the permission to send animals over 30 months of age and their meat product to the U.S. currently (USDA, ERS, 2016).

Also, in 2008 according to the country-of-origin labeling law, import of feeder cattle from Mexico becomes banned. The reason was the rising cost of managing imported animals (exchange, 2006).

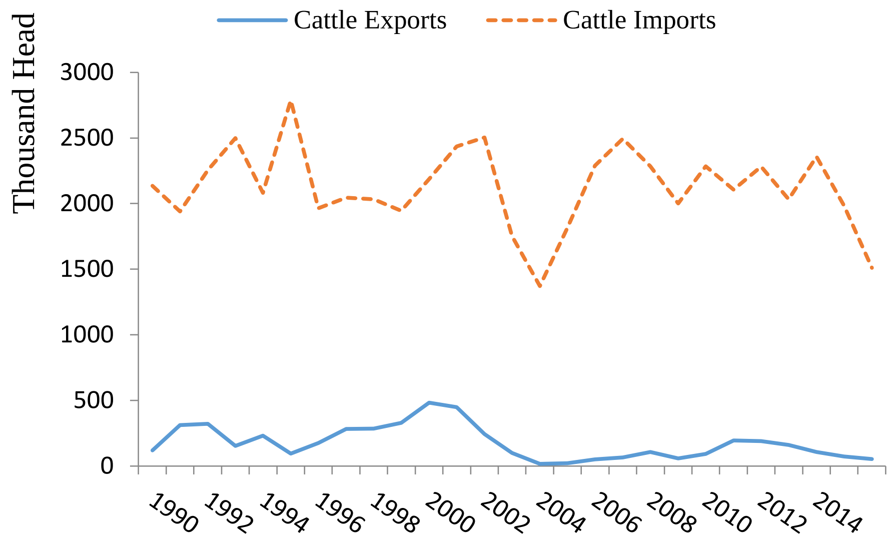

Figure 1-5: U.S. Cattle Trade during 1990-2015

Data Source: USDA, Economic Research Service, Livestock and Meat Trade Data.

Chapter 2. Vertical Price Transmission in the U.S. Beef Markets with a Focus on the Great Recession

This chapter is reproduced from a published manuscript, Darbandi, E., and S. Saghaian (2016). "Vertical Price Transmission in the U.S. Beef Market with a Focus on the Great Recession" Journal of Agribusiness **34**(2): 91-105.

2.1. Introduction

The consumption of meat is significant in the United States and about 4% of consumer disposable income and 30% of food expenditures are allocated to meat and poultry products. Per capita meat consumption (red meat and poultry) increased over the past decades up to 2007 (Darko and Eales, 2013). The importance of meat in general, and beef in particular, in the United States can be reflected in per capita consumption. Beef had the highest per capita consumption (pounds) among other kinds of red meats from 2000-14. Furthermore, beef has a higher price than lamb, pork, and broiler composite. The average per capita disappearance for beef, pork, and lamb is 62.2, 49.3, and 1.03 pounds, respectively during 2000-14.

Studying beef price interaction is beneficial because it would lead to better recognition of the beef market. As Goodwin and Holt (1999) asserted, price is the principal mechanism by which various levels of a market are connected. The magnitude of price adjustments in the presence of the Great Recession as a real exogenous shock affects price and consumption patterns. Retail prices had an increasing trend that reached its maximum by August 2008, while per capita food expenditures in the United States dropped.

The issue of price transmission can be discussed from the vantage point of agricultural policy reforms. The presence of an asymmetric price transmission would lead to over-estimating the benefit of a support policy for final consumers (Vavra and Goodwin, 2005). According to agricultural policy reforms in the United States since 1985 (The Food Security Act of 1985, the Federal Agriculture Improvement and Reform Act of 1996, the Farm Security and Rural Investment Act of 2002, and the Food, Conservation and Energy Act of 2008), high support is allocated to the dairy sector, while the large beef sector is among the sectors that receive little support. Generally, support policies are inversely related to market prices, this means that the level of support to producers increases when market prices fall (Diakosavvas, 2011). Policy makers and agricultural economists have concerns about the process of price transmission (Vavra and Goodwin, 2005). It is believed that in the presence of oligopolistic behavior and market power, prices are transmitted imperfectly along the supply chain. That is, a reduction at the farm level prices is slowly and not fully conveyed to final consumers, while a price increase at the farm level is transmitted through the supply chain quickly (Vavra and Goodwin, 2005).

Also, vertical price transmission of a shock at different stages of the beef market such as farm, wholesale, or retail levels is a significant attribute explaining the operation and efficiency of the entire value chain. The price adjustment in response to a market shock has important policy implications for marketing margins and mark-up price practices. In the absence of complete pass-through, price information is not available to all economic agents and this could lead to inefficient outcomes because of distorted decisions (Sarris, Hallam, and Rude, 2007).

Studying beef price relationships along the marketing channel will help policy makers be aware of the effects of an exogenous shock on different stages of this market and its impact on policies such as the Livestock Compensation Program or the Emergency Livestock Feed Assistance Program. This study investigates how different stages of the U.S. beef market adjusted in response to an exogenous shock such as the Great Recession. There are two main objectives in this study: first, the speed of the U.S. beef price adjustment, using Vector Error Correction Model (VECM); and second, the magnitude of price adjustments during the Great Recession, using historical decomposition graphs. The results show that prices adjust slower in the retail sector in response to the shock, which implies the consumer side was more affected by the shock.

In the following section, the Great Recession and some statistics about the U.S. beef market are provided. Then the related literature of price transmission is reviewed. After that, the conceptual framework, econometrics model, and data are explained. The empirical result section reports the VECM results and historical decomposition of the beef price series. The next section discusses the related diagnostic test and robustness of the results; and, finally, the summary and concluding remarks are presented.

2.1.1. The Great Recession

An economic shock that changed the social and economic life in the United States was the Great Recession. It began officially in December 2007 and ended in June 2009, which was called the longest economic downturn since the Great Depression of the 1930s (Grusky, Western, and Wimer, 2011), and caused incomparable monetary and fiscal policy reactions (Hanson and Essenburg, 2014). During U.S. postwar history, the most severe phenomenon was the Recession from 1981 to 1982, which lasted only 16 months and did not bring about labor-market disruptions as profound as those that occurred during the Great Recession (Grusky, Western, and Wimer, 2011).

The Great Recession has three different features compared to previous recessions. First, the decline in consumption per capita was greater than 3% from the last quarter of 2007 to the second quarter of 2009. Second, it was the longest economic downturn since the Great Depression. Third, consumption inequality declined among different age, race, education, and wealth groups because of its varying effects. This finding may seem confusing. The reason for a decrease in consumption inequality is the fact that, during the Great Recession, rich individuals lost a large fraction of their “buffer” wealth, which was supposed to be used for smoothing their consumption patterns. This matter affected their consumption behavior. Another explanation for the decline in inequality is due to a large reduction in the 90th percentile of nondurable consumption (Grusky, Western, and Wimer, 2011).

2.1.2. The U.S. Beef Market

As the largest beef producer in the world, the United State is a leader in producing high quality and grain-fed beef for domestic and world markets. Total beef supply in the United States during 2015 was 23,760 million pounds. Although the United States is the largest exporter of agricultural products in the world, it is a net importer of beef and purchases lower value and grass-fed beef for processing purposes, mainly as ground beef

(U.S. Department of Agriculture (USDA), 2016). The trends in beef imports and exports are reflected in Figure 2-1.

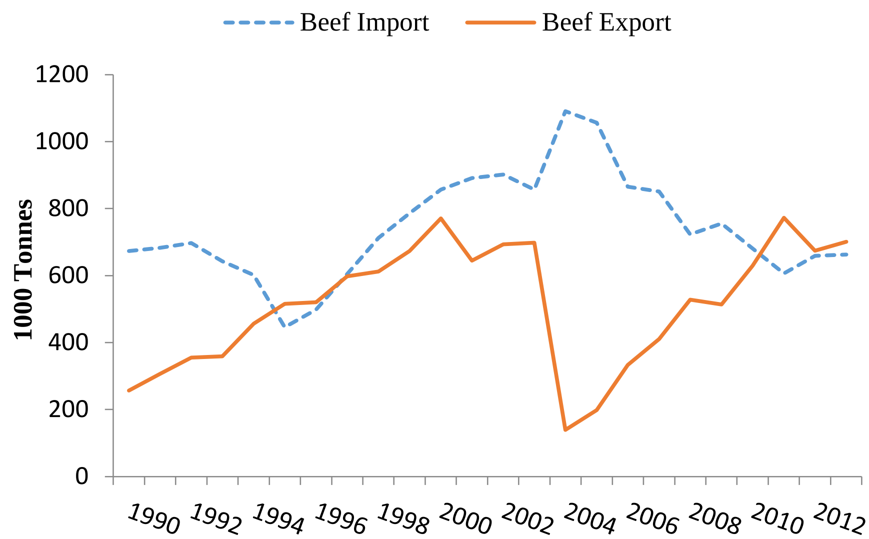

Figure 2-1: Trend in the U.S. Beef Import and Export from 1990 to 2013

Source: FAOstat database

It is obvious in Figure 2-1 that there is a huge decrease after 2003 in U.S. beef exports. The reason is many importing countries either forbade or limited beef and cattle shipments from the United States in response to bovine spongiform encephalopathy (BSE),[1] discovered in December 2003. The BSE discovery caused a remarkable reduction in U.S. beef exports in 2004. Japan and South Korea, two of the largest importers, were among countries which refrained from any imports of U.S. beef. Even later, in 2006 and 2007, when these countries restarted their beef imports from the United States, there was a restriction for beef from animals 20 months or younger, and 30 months or younger for Japan and South Korea, respectively (USDA, 2016). In the meanwhile, beef imports show a downward trend after 2003. Canada, Australia, and New Zealand are important suppliers of beef to the United States. In May 2003, Canada reported the discovery of BSE and, after that, imports of beef and cattle from Canada into the United States were banned. Also, the importing trend has continued to diminish

1- Bovine Spongiform Encephalopathy is a fatal neurological disease that can occur in adult animals aged five years or older because of reductions in the U.S. dollar value relative to the Australian dollar since 2009, and shortages of beef supplies in Oceania due to drought conditions (USDA, 2016).

According to the USDA, Americans consumed 115.6 pounds of red meat (beef, veal, pork, and lamb) in 2015; this average for 2014 was 112.1 pounds that includes carcass weight, retail, and boneless retail weight. From this total amount, the average per capita disappearance for beef is 61.1 and 60.8 pounds in 2014 and 2015, respectively. Beef is the most consumed red meat in the United States. Table 2-1 provides summary statistics of quarterly retail weight per capita disappearance (pounds).

Table 2-1: Summary Statistics of Per Capita Consumption (pounds), 2000 (1) - 2014 (4)

Variable	Average	Std.Dev	Minimum	Maximum
Beef	62.55	4.57	54.14	67.8
Pork	49.28	2.19	45.69	51.91
lamb	1.03	0.11	0.84	1.18

Source: Research calculation based on USDA Economic Research Service

In the United States, there are three kinds of beef available to consumers that vary in their quality levels. The grades are decided based on measurements of beef tenderness, juiciness, and flavor by USDA meat graders' subjective assessments, and by electronic instruments. Prime, choice, and select are the three quality grades awarded. Most of the graded beef sold in the supermarkets is either USDA Choice or USDA Select (USDA, 2012; Surathkal, Chung, and Han, 2014). The wholesale cutout beef data from USDA's Agricultural Marketing Service (AMS) (2013) show that the shares of Choice, Select, and Prime in total graded and branded beef products are about 47%, 36%, and 1%, respectively. This study relies on Choice grade beef that has the highest production level. However, Prime beef is considered as the highest quality grade based on marbling and is generally sold in restaurants and hotels rather than supermarkets. The Choice grade is considered to be superior in quality to the Select grade (Surathkal, Chung, and Han, 2014).

Figure 2-2 depicts the monthly nominal prices for beef at retail levels of the U.S. beef market from December 2007 to June 2009 that includes the period of the Great Recession.

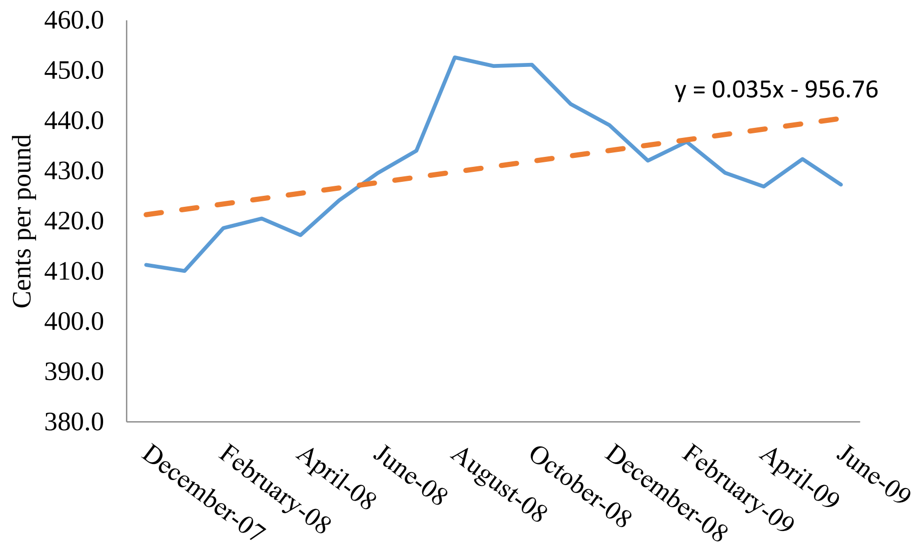

Figure 2-2: Trend in Nominal Retail Beef Prices in the U.S. during the Great Recession

Source: Bureau of Labor Statistics (BLS) retail price data

Note: Dashed line is the estimated trend line by author

Retail prices had an increasing trend that reached its maximum by August 2008. In the meanwhile, per capita food expenditures in the United States dropped (Figure 2-3).

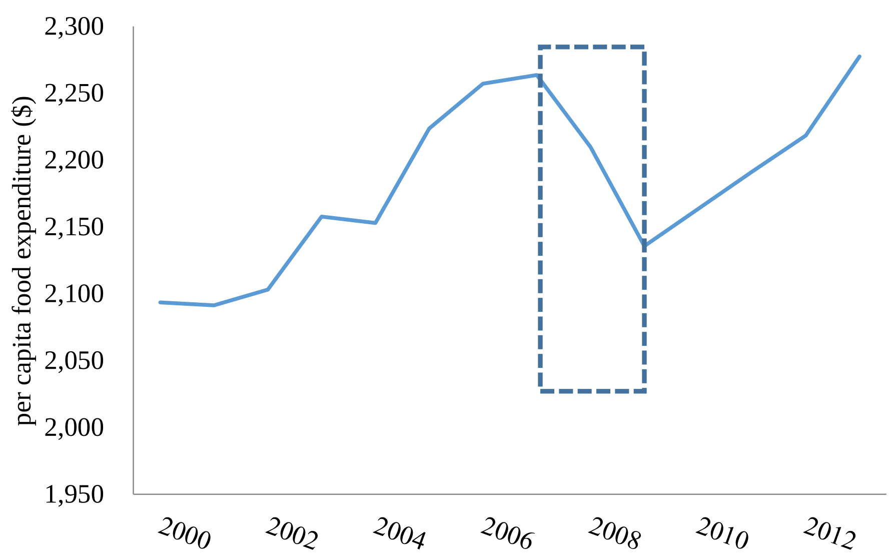

Figure 2-3: Trend in Per Capita Food Expenditure in the U.S. during 2000-2013

Source: Economic Research Service data

Note: the dashed line covers the period of the Great Recession

Noticeably, personal consumption expenditures decreased during the Great Recession. However, disposable income showed a different trend due to a significant increase in government transfers to households. These transfers were in the forms of unemployment insurance and the Supplemental Nutrition Assistance Program (SNAP, also known as food stamps). At the same time, wages and other financial income declined by 6.6% and 15.1%, respectively, as a result of the Great Recession, while government transfers grew 18.8% from 2007 to 2009 (Grusky, Western, and Wimer, 2011) (Figure 2-4).

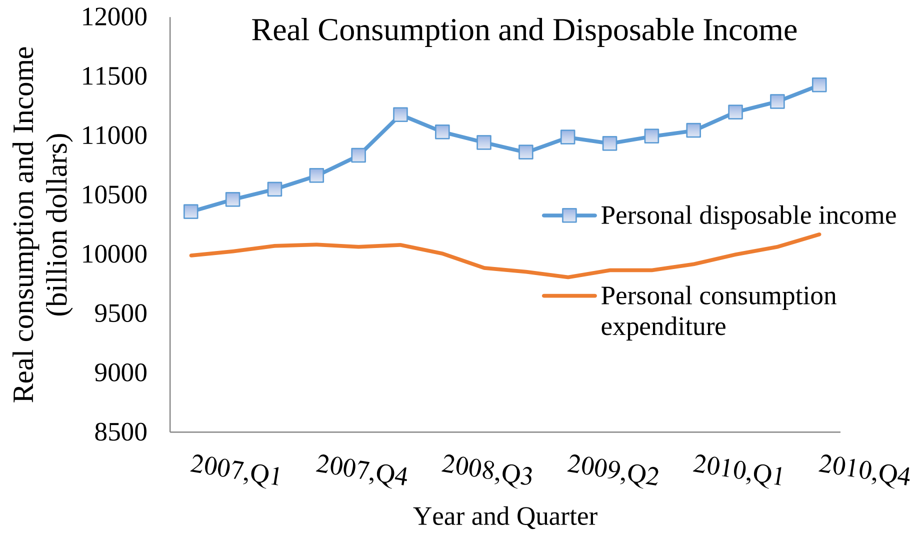

Figure 2-4: Real Per Capita Consumption and Disposable Income

Source: The U.S. Department of Commerce, Bureau of Economic Analysis

2.2. Literature Review

In a competitive market, it is expected that the effects of a policy are transferred fully to consumers. However, some empirical studies in the U.S. meat market reported that the price transmission was faster when there was an increase in the upstream market prices compared to when there was a decrease (e.g., Hahn, 1990; Goodwin and Holt, 1999; Vavra and Goodwin, 2005; and Pozo, Schroeder, and Bachmeier, 2013). While numerous studies have addressed the price transmission along vertically linked markets for agricultural products, most of the earlier studies used a model based on the Wolffram-Houck specification to investigate the pass-through among different markets (e.g. Kinnucan and Forker, 1987; Pick, Karrenbrock, and Carman, 1990; Zahng, Fletcher, and Carley, 1995). This specification was criticized by Goodwin and Holt (1999) due to their ignoring important properties of time-series data after they studied the price transmission in the U.S. beef sector, using weekly data and Threshold Vector Error Correction Model (TVECM). Also Carmon-Taubadel (1998) addressed the limitations of the standard models of asymmetry and discussed the inconsistency of those models with cointegration between prices by modifying the standard Wolffram specification, including an error correction term. This modification allowed looking at the long-run relationships among price series.

Recently, Pozo, Schroeder, and Bachmeier (2013) compared vertical price transmission in the U.S. beef market using two sources of retail prices which differ in their collection procedures. One of the retail price series is collected using electronic scanner data at the point of sale, and the other one is collected by the U.S. Bureau of Labor Statistics. They used a threshold cointegration approach and monthly prices for 2001-12 and tested how the use of different retail prices will affect price transmission results.

With a few exceptions (Saghaian, 2007; and Saghaian, Ozertan, and Spaulding, 2008), previous studies did not discuss any specific real shocks and merely looked at the speeds of adjustment. In these two above-mentioned studies, the effect of a fatal disease on the U.S. beef market and the impact of Avian influenza on the Turkish poultry sector were discussed, respectively, as exogenous shocks. Results of both studies confirm a differential impact on different levels of each market. This study refers to the Great Recession as a real exogenous shock and discusses the magnitude of adjustment in the presence of this shock.

2.3. Conceptual Framework and Estimation Approach

The basic model to study vertical price transmission was introduced by Wolffram (1971) and modified by Houck (1977). This model has been used in numerous studies in agricultural economics (e.g., Hahn, 1990; Boyd and Brorsen, 1998). However, Von Cramon-Taubadel (1998) argued that this specification is not appropriate to test asymmetric transmission because of its inconsistency with cointegration between prices at various levels of a market. Mathematically, based on the Wolffram-Houck specification, the relation between two levels of prices, P_i and P_j can be estimated by the following equation:

$$\sum_{t=1}^{T} \Delta P_{i,t} = \beta_0 + \beta^+ \sum_{t=1}^{T} \Delta P_{j,t}^+ + \beta^- \sum_{t=1}^{T\tau} \Delta P_{j,t}^- + \varepsilon_t \quad (1)$$

where $\Delta P^+$and ΔP^- show the positive and negative changes in prices, respectively, β_0, β^+,and β^- are coefficients and τ is the time period. If $\beta^+$and β^- are equal, then the price transmission is symmetric.

Although many empirical studies used the above specification to test the symmetry (e.g. Zhang, Fletcher, and Carley, 1995; Pick, Karrenbrock, and Carman, 1990; and Kinnucan and Forker, 1987), this model has been criticized because it ignores the nature of time-series data. In other words, in all of the above-mentioned studies, the problem of first-order autocorrelation exists. This problem arises from non-stationary time-series data and leads to spurious regression (Von Cramon-Taubadel, 1998). In order to avoid the problem of spurious regression in this study, first stationarity tests are applied and then an appropriate model is used to check the price relations. The Augmented Dickey-Fuller (ADF) test, which is widely used in empirical studies, is used in this study to check the stationarity of variables. The advantage of the ADF test is that it considers the possibility of higher order correlation by assuming that a series follows an autoregressive (AR) process. The null hypothesis of the ADF test is that series have a unit root. It implies the series is not stationary and the mean and variance are not constant over time (Dickey and Fuller, 1979).

Another, more important, step is to check for structural breaks in the dataset. Perron (1989) found that results of unit root tests can be influenced by the presence of structural changes in time-series data. The way that we investigated this issue was twofold. First, by applying Perron’s (1989) approach, we assured all series are stationary even if there is a structural break in a series. Then we investigated the structural break issue in the estimation process. Ignoring structural breaks in estimation could lead to unreliable estimates of price relationships (Boetel and Liu, 2010). For this purpose, we used the Quandt-Andrews break point test. We also compared the results of this test with the findings of Boetel and Liu (2010) that investigated the structural changes in vertical price relationships in the U.S. beef and pork markets. They used monthly data for the period January 1970 to February 2008 that covers almost the same time period of our research.

After checking the stationarity and structural breaks, the second step was using Johansen's cointegration test to determine if a long-run relationship exists among the price series. Based on the results of the stationary and cointegration tests, it can be decided if VECM is an appropriate model to fit the data. Cointegration techniques are useful to test the extent of price transmission along the market levels (Saghaian, 2007). The Johansen and Jeselius technique is very popular for estimating a group of cointegration relationships (Johansen, 1991; Johansen and Jeselius, 1992). This technique begins with a Vector Error Correction (VEC) model as follows:

$$\Delta X_t = \alpha_0 + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-1} + \Pi X_{t-k} + \varepsilon_t \qquad (2)$$

where, X is a p-element vector of observations on all variables in the system at the time t, α_0 is a vector of intercept terms, $\Gamma_i \Delta X_{t-1}$ term accounts for stationary variation related to the history of variables, and Π matrix contains the cointegration relationship. In this study, X is a 3×1 matrix, since there are three price series. All variables must be non-stationary in levels, and it is hypothesized that $\Pi = \alpha\beta'$, where β is a matrix combining the cointegration vectors. This cointegration requires that the β matrix contains parameters such as Z_t, where $Z_t = \beta' X_t$ is stationary. In other words, the β matrix contains the cointegration vector that represents the underlying long-run relationship. Also, the α matrix represents the speeds at which each variable changes to return to its respective long-run equilibrium after a temporary shock (Saghaian, 2007; Schmidt, 2000; and Johansen and Juselius, 1992) .

2.4. Data Description

The beef price data used in this study is related to the Choice grade. Data are collected from USDA, Economic Research Service (ERS). It should be noted that some researchers use scanner data for the retail level. The reason that we did not use the scanner data and relied on the USDA is that its dataset is more appropriate for the purpose of price analysis. Hahn, Perry, and Southard (2009) discuss that the scanner data, which are reported with a 7- to 8-week lag, contribute little to price analysis due to timing issues. We consider monthly data for the period of January 1970 to December 2014 to take advantage of a longer period. Descriptive statistics of the price series are provided in Table 2-2.

Table 2-2: Descriptive Statistics of Continuous Price Series (1970-2014)

	Farm	Wholesale	Retail
Mean	152.70	178.44	290.16
Median	145.45	171.45	279.05
Maximum	367.00	388.20	631.00
Minimum	58.80	71.50	98.00
Std. Dev.	52.61	58.51	116.70
Skewness	1.02	0.82	0.54
Kurtosis	4.93	4.21	2.87
Observations	540	540	540

All nominal prices are in cents per pound

Source: Research calculations

2.5. Empirical Results and Discussion

As discussed earlier, it is important to check the stationarity and structural break issue before running the pass-through regressions. The ADF and Phillips-Perron (PP) tests are used for this purpose; results are reported in Table 2-3. Based on the ADF test, the null hypothesis of a unit root for the price series cannot be rejected. The first-difference of each series is then tested. The null hypothesis of a unit root at the 1% level of significance is rejected for each series. For the ADF, the lag lengths are chosen based on Schwarz Information Criterion (SIC). These results are consistent with previous studies such as Saghaian (2007), and Vavra and Goodwin (2005). Also, the PP test confirms that the price series are stationary at the first-difference levels.

Table 2-3: Stationarity Test Results

Test in	level	First Difference	Level	First Difference
Variables	ADF	ADF	PP	PP
Farm prices	-0.42	-14.59***	1.32	-16.26***
Wholesale prices	-1.15	-17.19***	0.83	-20.67***
Retail prices	0.274	-16.00***	2.01	-17.64***

[a]: Mackinnon (1996) one-side P-value.

Critical values level are -3.975, -3418, and -3.131 respectively at 1%, 5% and 10% for ADF.

Test critical values are -3.44, -2.86, and -2.56 respectively at 1%, 5% and 10% for PP.

***, **, * indicates significance level at 1%, 5% and 10% respectively.

Source: Research calculations

Since all the series are integrated of one order, the next step is to check for the long-run equilibrium or cointegration. It is necessary to consider the structural break before applying the cointegration analysis. We relied on the results of previous research on the structural changes in the U.S beef market by Boetel and Liu (2010) which suggested there are four breaks in the beef price linkage equation. Nonetheless, three beef/cattle price series are cointegrated at the 5% significance level. In other words, the presence of breaks did not affect the cointegration results. We also considered the results of the Qundt- Andrew break point test to figure out any possible break specifically for the period of the Great Recession in our sample. The null hypothesis of no break point cannot be rejected for any of the equations. Therefore, we can rely on the results of the cointegration approach. The results are provided in Table 2-4.

Table 2-4: Johansen Cointegration Test Results

Unrestricted Cointegration Rank Test (Trace)

Null Hypothesis [a]	Eigenvalue	Trace statistics	0.05 critical value	Prob**
r = 0**	0.157	112.900	29.797	0.000
r <= 1**	0.034	20.800	15.494	0.007
r <= 2	0.003	1.921	3.841	0.165

Unrestricted Cointegration Rank Test (Maximum Eigen value)

Null Hypothesis [a]	Eigenvalue	Trace statistics	0.05 critical value	Prob**
r = 0**	0.157	92.097	21.131	0.000
r <= 1**	0.034	18.882	14.264	0.008
r <= 2	0.003	1.921	3.841	0.165

[a] r is the cointegration rank .

** denotes rejection of the hypothesis at the 5% level.

Source: Research findings

Johansen's test is a likelihood ratio (LR) test designed to determine the number of cointegration vectors in the system, or the cointegration rank *r*. Theoretically, *r* can be at most one less than the number of endogenous variables in the model (Saghaian, 2007). The results reject the null hypothesis *r*=0 and *r*<=1, but the null hypothesis *r*=<2 is not rejected (Table 2-4). This indicates that there are two vectors of long-run relationships.

As mentioned earlier, all the variables are stationary at the first-difference level, and a long-run relationship exists between them. Therefore, VECM is an appropriate model. Before estimating the final model, the appropriate number of lags was chosen. There are some criteria to do so, including SIC, Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC). Koehler and Murphree (1988) have compared AIC and SIC in time-series analysis. The results of this comparison shows that it is preferable to apply SIC, which leads to lower order models for predicting. Therefore, this study used SIC as the lag length criterion.

Table 2-5 provides the empirical estimates of the speeds of adjustment for the three price series, where ΔP_{ft}, ΔP_{wt} and ΔP_{rt} are the dependent variables of the models, which are related to the farm, wholesale prices, and retail prices, respectively.

Table 2-5: The Empirical Estimates of Speeds of Adjustment

Variable	ΔP_{ft}	ΔP_{wt}	ΔP_{rt}
Error correction term	0.034	0.223***	-0.115***
	(0.926)	(5.325)	(-4.618)
Model diagnostics			
R-squared	0.12	0.17	0.39
Akaike AIC	6.458	6.715	5.680
Schwarz SC	6.489	6.754	5.720

Note: ***, **, * indicates significance level at 1%, 5% and 10% respectively.

Numbers in parenthesis are t- Statistics
Source: Research findings

The coefficient of the lagged error correction term is interpreted as the short-term adjustment coefficient, and represents the proportion by which the prices adjust to reach the long-run disequilibrium. The *R*-squared values indicate the goodness of fit of the models which are 12%, 17%, and 39% for the farm, wholesale, and retail levels, respectively. The coefficients for retail and wholesale variables are statistically significant. These results are supported by Saghaian (2007), who used weekly beef price spreads during the period of January 5, 1991, to July 2, 2005, for feedlot, wholesale, and retail beef prices. He also found the speeds of adjustment were statistically significant for wholesale and retail levels.

In this study, the speeds of adjustment for retail and wholesale prices are statistically significant at the 1% level with estimated values of 0.23 and -0.11, respectively. The speed of adjustment for farm prices was 0.034, but statistically insignificant. The dynamic speed of adjustment for wholesale prices (0.223) in absolute value is larger than the one for the retail prices (0.115); this is an indication of asymmetric price transmission with respect to speed. This important result indicates that in the U.S beef sector, wholesale prices adjust much faster and are more flexible than the retail prices. In other words, it took more time for the retail prices to come back to the long-run equilibrium after the Great Recession had elevated the prices. It implies that the burden of a positive price shock is more on consumers than beef producers.

The asymmetric price transmission might be because of non-competitive market conditions; however, this hypothesis must be checked for the U.S. beef sector using appropriate modeling, which was not the purpose of this study. Some of the previous studies have listed several reasons for the cause of asymmetric price adjustments. Luoma, Luoto, and Taipale (2004 emphasized that the market power could be a good explanation for asymmetric adjustment. Conforti (2004) summarized six groups of factors affecting price transmission for agricultural markets: transport and transaction costs, market power, increasing returns to scale in production, product heterogeneity and differentiation, exchange rates, and border and domestic policies. All of these factors are related to both vertical and spatial price transmissions.

According to the results of the VEC model, the wholesale beef market is more competitive and operates more efficiently than the retail market with respect to the speed of adjustment. This result is consistent with what other researchers have found for U.S. beef markets. For example, Saghaian (2007) found that wholesale prices adjusted more than six times faster than the retail prices in response to a BSE shock, though there have been concerns regarding the high degree of packer concentration at the wholesale level. It is important to mention that in Table 2-5, the negative sign of the retail price and positive sign of the wholesale price coefficients imply that when the cointegration equation is out of equilibrium, wholesale prices tend to rise, whereas retail prices tend to fall, changing price margins. This point is elaborated in more detail using the historical decomposition graph in the next section.

2.5.1. Historical Decomposition Graphs

As discussed in the previous section, the speed of price adjustment along the U.S. beef supply chain varied from stage to stage. The other important aspect of the price transmission is the magnitude of price adjustment. In this study, historical decomposition graphs are used to measure this magnitude. The Historical decomposition traces the short-run dynamic effects of the beef market shock on the prices, which is helpful to develop a visual explanation of the impact of a shock in the neighborhood of the event. The graphs are decompositions of the price series from the structural VEC model (Saghaian, 2007). These graphs are based on partitioning the moving average price series into two parts, (Fackler and McMillin, 2002; RATS-Regression analysis of Time Series-2004), as follows in equation 3:

$$P_{t+j} = \sum_{s=0}^{j-1} \gamma_s U_{t+j-s} + \left[\beta X_{t+j} + \sum_{S=j}^{\infty} \gamma_s U_{t+j-s} \right] \tag{3}$$

where P_{t+j} is a multivariate stochastic process, U is multivariate noise process, X is the deterministic part of P_{t+j}, and S is a counter for the number of time periods. This study used the RATS [4] software to extract the graphs. The solid lines represent the actual prices, and predicted price are shown by the dashed lines. It is noteworthy that actual prices are influenced by the Great Recession shock. Although the dynamic impacts of any shock can last over a long time, the scope of this study is limited to the period of the Great Recession (i.e., December 2007 to June 2009). The results are shown at in Figure 2-5.

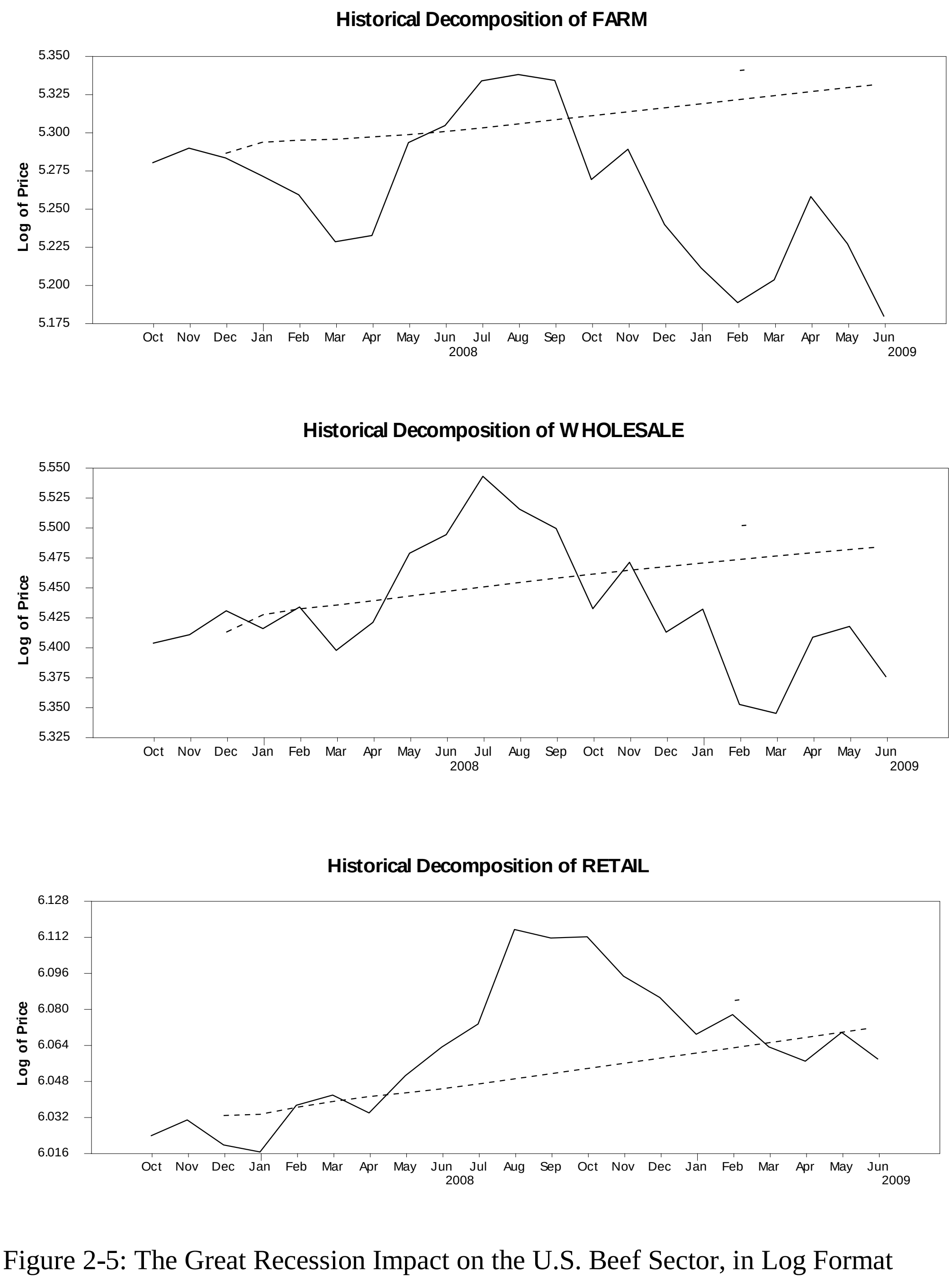

Figure 2-5: The Great Recession Impact on the U.S. Beef Sector, in Log Format

Note: Solid line and dashed line show actual and predicted price, respectively

Before the start date of the Great Recession, the actual farm, wholesale, and retail prices (solid lines in Figure 2-5) represent less volatility; but, after this date, sharp increases and decreases are observed in all three price series. Also, the retail price, in contrast to wholesale and farm prices, never returned to its original level (i.e., the beginning of the recession), while both the wholesale and farm prices experienced lower prices at the end versus the start date of the recession.

The historical decomposition graphs for all three prices indicated a sharp increase at some date, peaking, and then decreasing. Interestingly, the actual and predicted prices are equal at two end points. However, prices are different in terms of the dates for points A and B, and the length of the period between them (Table 2-6), where the actual price was higher than the predicted price (Figure 2-5).

Table 2-6: Comparison of Stages of the Beef Market in Two Points

Market	Peak	Point A	Point B	Length of the period AB (month)
Farm	Aug 08	Jun 08	Sep 08	4
Wholesale	Jul 08	Apr 08	Oct 08	6
Retail	Aug 08	Apr 08	Mar 09	11

Source: Research finding based on the historical decomposition graphs

According to Table 2-6, the period that the actual price is higher than the predicted is longer for the retail market compared to the wholesale and farm markets. Also, within the Great Recession period such as August 2008, the highest difference between actual and predicted prices is related to the retail level followed by the wholesale and farm levels. The intuition behind this point is that, in the short-run, an exogenous shock benefitted retailers more than the other players in the beef market.

In August 2008, the estimated magnitude of the actual farm price was 3.6% higher than the predicted price without the shock. Also, at the maximum point, the estimated magnitude of the actual wholesale price with the impact of the Great Recession was 9% higher than the predicted price without the shock. However, a huge drop in the wholesale prices occurred in March 2009 (one month after a huge reduction in farm prices). The difference between the actual and predicted wholesale prices at that time was about 13% (the same as the farm level). This indicates that the farm and wholesale prices mimicked each other very closely in relation to the one-month lag in decreases.

In August 2008, the estimated magnitude of the actual retail price with the impact of the Great Recession was 6.7% higher than the predicted price without the shock. The historical decomposition graph indicates that the wide departure between the actual and predicted retail prices was in May 2008 and lasted until March 2009. In contrast to the farm and wholesale price levels, no sharp reduction was observed in the retail price. Therefore, the benefits of a price increase were for retailers, with consumers paying higher prices for a longer period. This is consistent with the study by Saghaian (2007), who reported that an exogenous safety scare on the U.S. beef sector impacted producers and packers much more severely than retailers in terms of the magnitude of adjustment. In that study, the impact of a BSE shock on the U.S. beef sector was investigated. This shock was discovered in December 2003 and had a negative impact on the U.S. beef market, while in this current study, the Great Recession had a positive effect on the prices (Figure 2-5) and the trend of nominal retail beef prices was increasing over the period of the Great Recession.

In summary, the historical decomposition analysis confirmed that the emergence of the Great Recession had affected all the prices positively as expected, but the effects had been substantially different between various levels of the U.S. beef market. The historical decomposition graphs confirm the results of the VECM regarding the differential speeds of price adjustments. Both approaches attest to asymmetric price transmission in the U.S. beef marketing channel.

2.5.2. Robustness Tests

As the estimated results of the VECM in Table 2-5 showed, the relevant coefficients for the speeds of adjustment at the retail level and wholesale level were statistically significant. However, if the error terms are serially correlated, the estimated standard errors are invalid and the estimated coefficients will be biased. This issue can be investigated using an appropriate serial correlation test. Portmanteau and Lagrange Multiplier (LM) are two examples of common tests to check the autocorrelation in residuals (Bruggemann, Lutkepohl, and Saikkonen, 2006). In this study, the Breusch-

Godfrey (BG) test is based on the LM test. The BG test is sometimes referred to as the LM test for serial correlation.

Even though the Durbin-Watson (DW) test is very common for serial correlation, it is not appropriate in this study because DW is valid only when the following assumptions are satisfied: the model has a constant term, the serial correlation is of order one, and the lagged dependent variable is not included in the model as an independent variable. The results of the serial correlation test between the residuals are reported in Table 2-7. In this table, “Obs*R-squared” is the number of observation times the *R*-squared statistic, and has an asymptotic chi-squared distribution. The result of this test shows that the null hypothesis cannot be rejected. Therefore, there is no serial correlation between the error terms and, thus, the standard errors are reliable.

Table 2-7: Serial Correlation Test Results

Breusch-Godfrey serial correlation LM test			
Null Hypothesis: there is no serial correlation			
F-Statistic	2.078	Prob. F	0.126
Obs*R-squared	4.081	Prob. Chi-squared	0.129

Source: Research finding

In order to evaluate the robustness of the results of the estimated model, a subset of data has been chosen and the model is re-estimated. Table 2-8 displays the VECM results for the period 2000-14, including 180 monthly observations of each price series.

Using a subset of data in re-estimating the VECM, the results in Table 2-8, supports the previous results. The speed of adjustment that is reflected by the lagged error correction term is different for each price series, attesting the asymmetric price transmission. Again, the coefficients for both the wholesale and retail levels are statistically significant and the negative sign for the retail prices implies that they tend to decrease to reach equilibrium.

Table 2-8: The Empirical Estimates of Speeds of Adjustment

Variable	ΔP_{ft}	ΔP_{wt}	ΔP_{rt}
Error correction term	0.036	0.368***	-0.185***
	(0.549)	(4.484)	(-3.532)
Model diagnostics			
R-squared	0.14	0.23	0.40
Akaike AIC	6.901	7.309	6.420
Schwarz SC	6.990	7.398	6.508

*** indicates significance level at 1% - Numbers in parenthesis are t- Statistics

Source: Research findings

2.6. Summary and Conclusions

This study analyzed price adjustments in the vertical market channel of the U.S. beef market using monthly prices for the farm, wholesale, and retail levels for the period of 1970-2014. To address the dynamics of price adjustment along the channel, time series analysis including cointegration, VECM, and historical decomposition graphs were applied to address the speeds and magnitudes of price transmission. The estimation process can be summarized as follows: first, ADF and PP's unit root test were used to evaluate the time-series properties of the dataset. To investigate the long-run relation between variables, the Johansen cointegration approach was applied and then the VECM was used to estimate the speeds of price adjustments. An analysis of the magnitudes of price adjustments in the presence of an exogenous shock, i.e., the Great Recession, was discussed. The Great Recession, the deepest economic crisis in the modern U.S. economy, started in December 2007 and remained until June 2009. To compute the magnitude of price adjustments, historical decomposition graphs were applied to provide visual explanations of the shock.

Findings revealed that the retail level had a lower speed of adjustment (0.115) compared to the wholesale level (0.223); for the farm level, the speed of adjustment was not statistically significant. We found there was an asymmetric price transmission along the beef supply chain. The wholesale market showed itself to be more competitive, operating more efficiently than the retail market with respect to both speed and magnitude of price adjustments. This study concludes that the burden of a positive price shock is more severe for consumers than producers. One possible explanation can be the presence of market power at the retail end. The existence of huge supermarkets such as Walmart, Kroger, and Costco are some examples.

Another explanation for the slower speed of adjustment at the retail level is related to the retail price behavior. Some retailers don't believe their customers want to see rapid and frequent price changes and also have a high-low pricing strategy. In other words, they price their meat at very high prices (big margins) and then feature beef at reduced prices to encourage shoppers to visit their store to purchase beef and other items to completely fill their shopping basket. Retailers know there are cycles in the cattle/beef business. They are willing to live with inconsistent margins, meaning that when they face the beef cycle with tight supplies, they understand margins will be tighter, but when beef supplies are increasing, their margins will widen. (This is the case today in late 2016; retailers have their widest margins in history when compared to producer prices for cattle).

Government intervention can also impact the efficiency of the markets. It may be the reason that there are powerful meat trade and lobbying organizations in the United States such as the American Meat Institute, the National Meat Association, and the National Cattlemen's Beef Association. These groups lobby for less government involvement and free markets. We suggest the government agencies and meat industry organizations work together to finalize regulations in the meat industry. It is naïve to say government should control the retail prices when a recession hits. Instead we encourage considering the meat industry insights in any rulemaking process. The previous experiences confirm this claim. For example, in 1996, the new food safety regulation was objected to by the meat industry, especially because of testing for salmonella bacteria in ground beef. These kinds of complaints cause significant delay in the implementation of a new, suggested policy from government. Incorporating the perspectives of government agencies and meat industry representatives can result in more efficient outcomes and facilitate the implementation process.

Previous studies (e.g., Conforti, 2004) have suggested many other reasons as the causes of differential and asymmetric price adjustment in the agricultural markets, including transport and transaction costs, increasing returns to scale in production, product heterogeneity, and differentiation. Among these reasons, market power in the retail sector seems to be more relevant to the U.S. beef market; however, this is beyond the scope of the present study and future studies to investigate this hypothesis are encouraged.

Chapter 3. The Impact of Consumer Beef Safety Awareness on U.S. Beef Exports

3.1. Introduction

In the last few decades, debates about food safety events have extended from public health to international trade and become a global issue. Widely reported food safety events affect consumer perception of safe food, and lead to variations in food purchasing habits (Satcher, 2000; Buzby, 2003; Regmi, 2001). Also, these events affect consumers' willingness to pay (WTP) for safe food (Saghaian, *et al.*, 2008). For example, the results of a survey in 1997 revealed that after the mad cow crisis in Europe, French consumers agreed to pay 14-22% higher premium for safe beef (Latouche, *et al.*, 1998). In addition, following the 2001 mad cow outbreak in Japan, Japanese consumer's WTP for a premium to purchase safe beef was more than 50%. Japanese are known for their high WTP for healthier food (McCluskey, *et al.*, 2005).

Generally, the population growth, urbanization, and higher income levels have increased demand for safe nutrition and food (FAO, 2017). The world's population is expected to reach 9.6 billion in 2050, which requires 70% more food than 2006. Meanwhile, consumption patterns are changing. A study by FAO revealed that the global diet has changed toward consumption of more livestock products, fish, vegetable oils, and sugar, especially in the developing countries (FAO, 2012). Beside the growing demand for food in general, the demand for healthier food has also increased considerably. Chen and Saghaian (2017) discuss that with the rapid growth in the U.S. organic sector, organic product sales reached $39 billion in 2014, more than ten times higher than 1997. The emergence of new labels on different products, such as the organic label, gluten-free, non-GMO[2], and RBST[3]-free, are all evidence of increased consumer interest for healthier and higher quality food.

In addition to the health-related concerns, the safety incidents cause remarkable cost and economic burden annually (Saghaian, Ozertan, and Spaulding, 2008). By one

2- Non-Genetically Modified Organisms
3- Recombinant Bovine Somatotropin is a growth hormone used in dairy farming to increase milk production.

estimate, the total cost of foodborne illness exceeds $77 billion per year in the U.S. (Scharff, 2012). While this is a noticeable loss, it only represents health-related costs, and does not include financial damages to the food industry due to other costs such as food-recalls or litigation. For example, the government spent $1.3 billion to response to the BSE[4] in Japan (Fox and Peterson, 2002).The history of mad cow disease discovery traces back to 1986 in the United Kingdom. Those events caused beef consumption to decline remarkably, and the estimated losses to society were $1.7 billion (Taha and Hahn, 2014).

An important issue is that national borders do not restrict foodborne diseases. The international food supply chain can potentially help spread food diseases worldwide. Contaminated food in one country can spread and lead to illness in other geographical areas and cause significant human loss and suffering (Regmi 2001, and Satcher 2000). Importing countries are usually very sensitive to food safety events in exporting countries and limit imports in order to protect their consumers. For example, the discovery of mad cow disease in a slaughtered Holstein in Washington in December 2003 led to a sharp decline in the U.S. beef exports. After the mad cow disease discovery, the U.S. lost its rank as the world's third largest exporter of beef[5]. In 2016, the U.S. was behind Brazil, India, and Australia as the top beef exporters (USDA, 2017). Hence, the loss of export markets due to import bans is a major consequence of food safety scares.

Economic burdens of foodborne incidents become intense when the media publicize and magnify food safety events. Previous events around the world have shown that the official announcement of food scares could have a dramatic impact on consumer behavior. For example, after the mad cow discovery in the United Kingdome in 1986, consumer preferences shifted toward other meats such as chicken, and domestic sales declined 40% by 1996, ten years after the mad cow discovery. This happened when the British government publicized a possible relation between mad cow disease and variant Creutzfeldt-Jakob disease (vCJD), which is the human form of mad cow disease. As

4- Bovine Spongiform Encephalopathy (BSE) or mad cow is a fetal neurological disease that can occur in adult animals, aged five years or older.

5- One noticeable fact is that when a food disease is recognized in an exporting country, although the country may regain the market share over time, but it may have to switch from higher value markets to lower value markets. Lower value markets are those that have had the food safety issues in the past. Webb *et al.* (2017) provide more numerical details about this issue.

expected, the sharp drop in beef consumption occurred not only in the domestic market, but also in many other countries (Taha and Hahn, 2014). In addition, a publicized report by a Japanese meat company that had claimed imported beef was the main cause of BSE discovery in Japan attributed to part of the loss in the U.S. beef exports to Japan in 2002 (Jin and Koo, 2003).

The present study is an attempt to investigate how consumer awareness has affected the U.S. beef exports over time. We construct an index that reflects consumer awareness about foodborne outbreaks and quantifies the relationship between publicized beef safety outbreaks and U.S. beef exports. The rest of this study proceeds as follows. We first review the literature related to food safety events, and briefly review some free trade agreements. Then we present the methodology and describe the dataset used. We then present the results and discussions. Finally, we provide the concluding remarks.

3.2. Literature Review

There are many research articles about beef safety incidents. Some of the studies have investigated the effect of a disease outbreak within a country on domestic demand for meat (Burton and Young, 1996; Yeboah and Maynard, 2004; Saghaian, *et al.*, 2008; among others). One remarkable finding is that in the aftermath of the BSE discovery in Japan in 2001, consumption of both domestic beef and imported beef dropped. Although the disease was not found in the U.S. herd cattle, Japanese avoided consuming U.S. beef as well. In addition, Jin (2008) found Korean consumers reacted negatively to the Japanese BSE outbreak by decreasing their meat consumption, while the disease was not reported in South Korea. Researchers attribute this to consumers' perception from public media. Jin (2008) believes that the huge volume of media reports and attention changed the preferences of Korean consumers. Furthermore, previous research (e.g., Fox and Peterson, 2002) have shown that after receiving mass media reports about food safety incidents, consumers immediately take action and change their consumption behavior. Another group of studies has specifically focused on the effect of media coverage on domestic meat demand in the presence of a food safety event. For instance, Verbeke and Ward (2001) and Verbeke, *et al.* (2000) showed the negative impact of media coverage on domestic meat demand after the Belgian BSE event.

The above-mentioned studies utilize wide varieties of econometric approaches such as contingent valuation, the AIDS model, the Rotterdam model, and historical decomposition, among others. This group of studies report a structural change in meat consumption in the aftermath of a foodborne crisis and a shift away from beef consumption toward other kinds of meats including fish and poultry. Fewer studies have looked at the effect of a beef safety incident within a country on its beef export levels. For example, Taha and Hahn (2014) argued that there was a structural change in the U.S. beef exports because of the BSE discovery in the U.S.

Some food safety studies focus on the role of food safety regulations and standards and conclude that food safety standards could affect trade flow positively. Li, *et al.* (2012) showed that implementation of a management system, Hazard Analysis Critical Control Point (HACCP) has a positive impact on U.S. seafood exports. This system is to control and assure seafood safety. In addition, Tan, *et al.* (2013) discussed the impact of GMO safety regulation on Chinese soybean exports. They conclude that labeling policy has a small effect, but the management system has a significant impact on exports.

Other recognized and publicly reported foodborne diseases include the Highly Pathogenic Avian Influenza (HPAI) that in 1997 started from Hong Kong, outspread to central Asia, Africa, and Europe, and caused 92 human deaths. Another example relates to the discovery of Avian Influenza (AI) in 2005 and 2006 in Turkey with four human death (Saghaian *et al.* 2008, World Bank, 2006).The most severe avian health disaster in the U.S. history that expanded across 15 states discovered in November 2014. Prior HPAI incidents happened in 1924, 1983, and 2004. In some cases, the risk to the public health was low. However, economic losses to the poultry industries were remarkable. For example, to control the 2014 outbreaks, more than 48 million birds were euthanized. Meanwhile, Russia, China, and South Korea imposed bans against all U.S. poultry imports (Greene, 2015).

3.3. Free Trade Agreements

The U.S.-Mexico free trade agreement began in January 1994. In addition, the free trade agreement between the U.S. and Canada was in force from 1989. In January 1, 2008, all tariffs between the three countries were eliminated (Amadeo, 2017). The Trans-Pacific Partnership (TPP) is another agreement between some countries, including Canada, Mexico, Japan, the U.S. and seven more. These countries signed the agreement in 2016, and it was supposed to replace NAFTA as the largest free trade agreement in the world (Amadeo, 2017). Another negotiated agreement is the Transatlantic Trade and Investment Partnership (TTIP), and is between two of the most developed economies, the U.S. and EU. However, the implementation of this agreement has some barriers. For example, both trading partners support their food sectors through subsidizing. On the other hand, EU (USTR, 2017; Beckman, et al., 2015) does not allow the use of GMOs in agriculture, and hormone and antibiotics in animals, which are common in the U.S. The existence of these types of agreements may help trade partners to overcome the economic burden arising from a foodborne outbreaks. Jones and Davidson (2014) discuss that the health concern from these outbreaks may affect the market access, such that exporting countries lose their market share.

When a foodborne outbreak occurs in a country, and the news is publicized widely, one of the consequences is that the contaminated country loses its reputation as the producer of safe food among consumers. As noted by Webb, Gibson, and Strutt (2017) the challenge of market access may remain a long-term challenge even after the outbreak is eradicated. The contaminated country may not restore the public confidence without cooperation with importing countries' policy makers. In addition, this issue becomes more challenging when even a free-disease country is adversely impacted as the result of the animal disease outbreaks out of its border. For example, when BSE was reported in Japan in 2001, the consumers refused to consume even the imported beef. Later in 2002, the Japanese government initiated a campaign to promote the claim that the Japanese beef is the safest in the world. By this aggressive and unilateral action that aroused suspicion on the safety of imported beef, the U.S. and Australian agencies had to launch high visibility advertising for their products (Fox and Peterson, 2002). Another study by Ono (2001) reports that McDonald's chain stores in Japan spent $4.1 million after the discovery of BSE in Japan to advertise that they were only using the Australian beef, which is grass-fed. They did this advertisment to convince their consyumer that their product is disease-free.

Although it is well understood that each government priority is to protect its people and economy, the existence of bilateral cooperation may lead to a positive welfare impact on all consumers ultimately. Establishing safety standards and sanitary conditions according to both importer and exporter expectations, are examples of bilateral cooperation. Otherwise, countries have to tolerate additional costs. Recently as of June 2017, the U.S. has banned the import of fresh beef from Brazil duo to food safety issues. Before that from March 2017, according to USDA, the Food Safety and Inspection Service had to take an additional step to re-inspect all imported meat from Brazil at the port of entry, when they found out that the Brazilian meat might have salmonella contamination (USDA, 2017). Undoubtedly, conducting re-inspection process and pathogen testing impose extra costs for the U.S.

Another issue related to accessing new markets is to be aware of characteristics and expectations of international consumers. Recently the U.S. share of beef exports to some countries has increased extraordinarily (see Table 3-1). Indonesia and Egypt have a large Muslim population with 87.2% and 90% of their populations, respectively, being Muslim. Ingoing this fact might hinder the growth in these particular markets. Recently, Indonesia's Ministry of Agriculture (MOA) set a new regulation that requires meat to be exported to Indonesia only if they have been slaughtered in establishments fully dedicated halal. This requirement results in restriction for the U.S. beef exports (USMEF, 2017). We conclude that in order to keep this export growth, it is necessary to value international consumers' attitudes. Furthermore, under these circumstances, the role of bilateral cooperation has a vital importance.

Table 3-1: New Accessed Markets for U.S. Beef

Country	Year-to-Date Quantity (Metric Tonnes)			Year-to-Date Value (US $1000)		
	Jan 2015	Jan 2016	% Change	Jan 2015	Jan 2016	% Change
Indonesia	45	290	544%	$528	$2,435	361%

Egypt	1	109	10800%	$17	$455	2576%

Source: Statistics provided by USDA and compiled by USMEF

In summary, the general theme across previous work demonstrates that consumers change their habits of meat consumption in the presence of a food safety incident. However, those studies do not quantify the effects of consumers' awareness and preferences on the export levels of meat products. In this study, we consider consumer awareness as a demand shifter that changes domestic and international demand for beef. Consumers' preferences are reflected in an index, which captures the media reports on food safety events. Piggott and Marsh (2004) calculated such an index to examine the impact of food safety information on domestic U.S. meat demand. The point that makes this work distinct from the former study is that we investigate the impact of consumer awareness on U.S. beef exports to major beef export destinations, while Piggott and Marsh (2004) considered the domestic meat market; they used quarterly data for the period 1982-1992. This study uses quarterly data for the period of 2000-2016 that allows investigating the impact of recent prominent foodborne outbreaks, such as the BSE discovery in 2003.

3.4. Model Development

We employ an innovative method, based on the cross-section gravity model, to illustrate the effect of consumer food-safety awareness on U.S. beef exports. We construct our model based on a theoretical model for international trade. Anderson (1979) argued that economic size and cost of transaction predict the trade flow between countries. Soloaga and Winters (2001) modified the cross-section gravity model by adding the real exchange rate variable. They discussed that when time dimension exists in the data, exchange rate becomes relevant. Since our data covers the time-period 2000 to 2016, following that study, we also modify the initial specification of the gravity model by considering the exchange rates for the importing countries.

Following Li, *et al.* (2012) and after adding the variable representing consumer beef-safety awareness based on media reports, equation (1) represents the initial model specification:

$$LnEXP_{it} = \alpha_0 + \beta_1 LnGDP_{it} + \beta_2 LnEXR_{it} + \beta_3 LnDIS_i + \beta_4 LnPRD_{it} + \beta_5 LnFOODSCARCE_t + \varepsilon_{it} \tag{1}$$

where EXP_{it} is the level of U.S. beef export to country i at time t. GDP_{it} is the gross domestic product of country i at time t and serves as a proxy for the size of the economy. DIS_i , which is a proxy of transaction cost, reflects the distance between each importing country to the U.S. The variable EXR_{it} is the exchange rate for U.S. dollar and domestic currency of country i at time t. PRD_{it} is the production level of beef in each country, and finally, $FOODSCARCE_t$ is the variable of our interest in this study representing consumer awareness about beef safety events over time. α_0 is the intercept, and ε_{it} is the error term.

The endogeneity problem is a possibility in this common specification of the gravity model that arises from the unobserved time-invariant heterogeneity between countries (Anderson and Wincoop, 2003). In the presence of endogeneity, the error term is correlated with other variables and the estimation results are biased (Li, *et al.*, 2012). To avoid the endogeneity problem, the common solution is to consider random effects or fixed effects in the econometric specification of the gravity models (Mátyás, 1997). To choose between these two effects, we use Hausman test in this study.

Anderson and Wincoop (2003) suggest considering the supply and demand factors in the gravity model specification. The variable GDP_{it} and PRD_{it} (level of beef production) relate to importing countries, and represen their demand. The variable $USPRD_{jt}$, which is U.S. beef production, is also incorporated a supply factor. In addition, we consider dummy variables for trade agreements (TA_{it}) between the U.S. and importing countries when it is in place. Canada, Mexico, and South Korea have had free trade agreements with the U.S. from 1989, 1994, and 2012, respectively. There is no free trade agreement between the U.S. and Japan (USDA- FAS, 2016). This variable equals one when there is an agreement and zero otherwise.

Hence, we modify the previous equation as the following:

$$LnEXP_{it} = \alpha_0 + \beta_{it} + \beta_1 LnGDP_{it} + \beta_2 LnEXR_{it} + \beta_3 LnDIS_i + \beta_4 LnPRD_{it} + \beta_5 LnFOODSCARCE_t + \beta_6 LnUSPRD_t + \beta_7 TA_{it} + \varepsilon_{it} \tag{2}$$

where β_{it} consists of unobserved effects of importing countries' heterogeneity to deal with the endogeneity problem. Finally, we run a panel VAR model to extract the impulse response functions to trace the impact of a shock in foodborne disease news on U.S. beef export.

3.5. Data Description

We used data for Canada, Japan, South Korea, and Mexico as the top importing countries (see Table 3-2). To measure the real GDP, this study uses GDP deflator (implicit price deflator)[6]. Quarterly data is collected from the Federal Reserve Economic Data (FRED) for this purpose. This data is seasonally adjusted and indexed as 2010=100. Beef production levels were collected from FAO for importing countries, and for U.S. beef production, we used the USDA database. Quarterly exchange rate was collected from Archival Federal Reserve Economic Data and then we adjusted the data as 2010=100.

Table 3-2: Leading Markets for U.S. Beef Exports

Country	Year-to-Date Quantity (Metric Tons)			Year-to-Date Value (US $1000)		
	Jan 2015	Jan 2016	% Change	Jan 2015	Jan 2016	% Change
Japan	11,192	13,452	20%	$74,014	$69,420	-6%
South Korea	6,594	9,927	51%	$54,701	61,367	12%
Mexico	10,278	7,245	-30%	$76,863	$48,160	-37%
Canada	9,029	8,067	-11%	$70,854	$52,594	-26%

Source: Statistics provided by USDA and compiled by USMEF

In this study, we use quarterly panel data for the period of 2001q1 to 2016q4 for all the variables. The descriptive statistics for the variables are reported in Table 3-3. The variable related to the trade agreement is a dummy variable.

5- GDP implicit price deflator is the ratio of the current-dollar value of GDP to its corresponding chained-dollar value, multiplied by 100 (Bureau of Economic Analysis, 2017).

Table 3-3: Descriptive Statistics of Quarterly Panel Data (2000Q1-2016Q4)

	Mean	Median	Minimum	Maximum	Std.Dev.
U.S. beef export (1000 pounds)	98565.3	91606.5	28	292232	60880.3
Importers' GDP (price deflator)	96.2	99.5	56.4	128.1	13.3
importers' beef production (million pounds)	456.8	398.08	93	913.58	284.4
U.S. beef production (million pounds)	6499.8	6532.0	5709.8	7164.1	327.8
Food scare index	46.7	40	11	135	26.73
Distance (km)	6470	6978	737.4	11185.9	4663.5
Exchange rate to U.S. dollar	311.01	48.56	0.96	1414	475.6
Number of observations	272				

Source: Research calculations

By comparing export levels and export values in the dataset, we notice the percentage change of these two variables are different over time. For example, U.S. export volume of beef to South Korea increased by 51% from January 2015 to January 2016, while the equivalent export value increased only by 12% (see Table 3-2). The difference between percentage changes in quantity versus export value can be due to inflation and price effects. In the above table, the maximum level of U.S. beef exports to a single country was to Japan in 2000q3. The minimum amount relates to 2004q1, immediately after the discovery of BSE in the U.S., exported to South Korea. There was a period of several months when the U.S. could not export beef as before due to import bans. Five months after BSE discovery in the U.S., Mexico restarted to import beef from the U.S. on the same levels as before. However, it took more than a decade for South Korea to import U.S. beef as much as the pre-BSE levels. It is noticable that although the level of U.S. beef and veal export to the importing countries remarkably dercreased but it was never equal to zero. In other words, we do not have to be worried about having a zero value in the dependent varibale. The minimum level for GDP corresponds to 2000q1 for Mexico. The highest beef production level also relates to Mexico, and the lowest relates to South Korea. In addition, the variable distance has the minimum and maximum value for Canada and South Korea, respectively.

Following Piggott and Marsh (2004), we constructed the index from newspaper articles. For this purpose, we searched among the top ten English language newspapers using the academic version of Nexis Uni (LexisNexis) search engine. Other languages are not available in this search engin. We used keywords, such as *food safety* or *contamination* or *product recall* or *outbreak* or *salmonella* or *foodborne*. From these results, we narrowed our search and collected data for beef products for every month in the period 2000-2016. Then, we linearly aggregated the data to construct a quarterly index. This index is a proxy for consumer awareness about beef safety.

The minimum level for the beef-safety index corresponds to the second quarter of 2016, and the maximum relates to the first quarter of 2001. In addition, this index took the value above one hundred in the period 2003q2 to 2004q1, relevant to the discovery of BSE in Canada and later in the U.S. The results of foodborne disease news for beef are used to construct the food safety index (See Figure 3-1). However, if we include the other meats, there are large numbers of news relevant to U.S. E.coli outbreak in 2015-2016 that were mainly associated with chicken products [7] (FDA, 2015). As we can see in Figure 3-1, there are three periods with large numbers of media reports. The first and the second apexes are related to the BES discovery in Japan in 2001, and then, in Canada and the U.S. in 2003. The third peak relates to the 2008 U.S. salmonellosis outbreak.

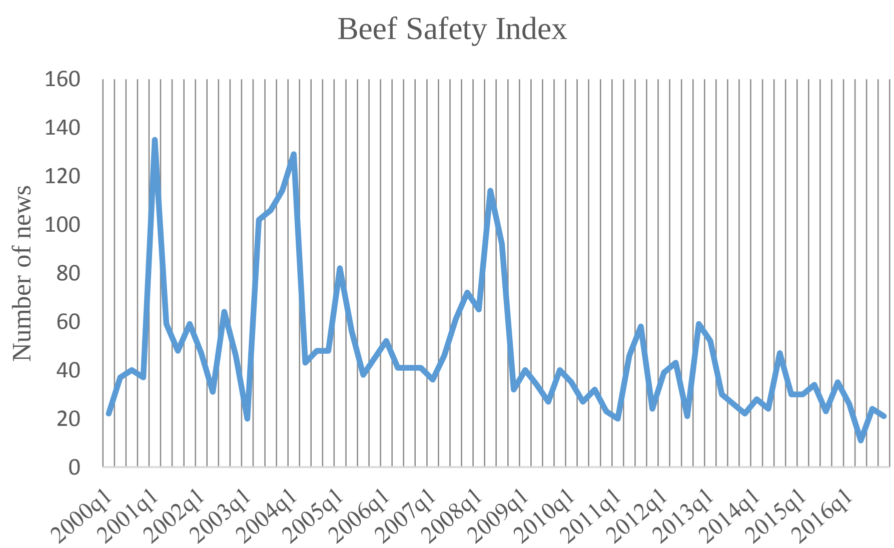

Figure 3-1: Beef Safety Index Related to Foodborne Disease Mainly from Beef Products

Source: Research findings

7- U.S. Food and Drug Administrations (FDA) investigations suggested that rotisserie chicken salad purchased from Costco stores was a possible source of this outbreak (FDA, 2015).

3.6. Empirical Results

Table 3-4 reports the result of Hausman test to choose between the fixed effect and random effect models. The null hypothesis is that the random effects is preferred due to higher efficiency. Based on this test, we follow the estimation with fixed effects.

Table 3-4: Hausman Test Result

Test Summary	Chi-sq statistics	Prob
Random effect is preferred	55.88	0.000

Source: Research estimations

The estimation results for the fixed effects model are reported in table 3-5. The dependent variable is the volume of U.S. beef exports to the top four importing countries.

Table 3-5: Result from Estimation of Gravity Model with Fixed Effect

Variables	Coefficient	t-statistics	p-value
Importers' GDP	-0.840	-1.23	0.220
Importers' beef production	2.525**	2.88	0.004
U.S. beef production	8.177***	4.91	0.000
Beef safety index	-0.540**	-3.14	0.002
Distance	-108912.9	-0.49	0.623
Exchange rate	0.448	0.74	0.461
Trade agreements	1.257**	2.71	0.007
Intercept	905068.6	0.49	0.623
Sigma-u	140602.57		
Sigma-e	1.315		
Number of obs	272		
F test that all u_i=0	F (3,261)=5.82		Prob > F =0.0007

Note: All explanatory variables are in Ln form except for "trade agreements" which is a dummy variable.

***, **, * Indicate significant at 1%, 5%, and 10% level, respectively.

Source: Research estimations

The signs for thr most of the estimated coefficients are as one expects, though some variables are not statistically significant. The GDP of importing countries dose not show a significant effect on U.S. beef export, also the beef production in importing countries dosen't have a significant effect. As we stated before these two variables reflect the demand for U.S. beef. An increase in the domestic beef production results in a lower demand for beef imports from U.S. This result consistents with those of Webb, Gibson, and Strutt (2017), but we are unable to draw the above conclusion because the variable is statistically insignificant. It could be related to the quality differentiation of beef products in importing countries and the United States. Such that, demand of importing countires for U.S. beef is not affected by their domestic production.

The coefficient for U.S. beef production is positive and statically significant, such that a one percent increase in U.S. beef production leads to a 8.1% increase in U.S. beef exports. The coefficient for consumer awareness about beef safety scares is negative, meaning it has an adverse effect on U.S. beef exports. It means that when consumers receive news about the occurrence of a foodborne disease, they negatively respond to the U.S. beef market, such that additional publicized report about a beef disease outbreak on official media leads to a 0.5% reduction in U.S. beef exports. The variable distance does not have a significant effect, while the sign is negative as expected according to the gravity model.

The Exchange rate is also statistically insignificant. The USDA has announced that the relative supremacy of the U.S. dollar is a challenge to grow exports in Mexico and Canada. However, some of the exchange rate impacts are negated by lower U.S. prices (USDA-FAS, 2017). The regional/bilateral trade agreements facilitate international trade by restricting trade barriers. The U.S. has several bilateral agreements with its trade partners. The results of our estimation support this idea and the coefficient for trade agreements has a positive and significant impact on U.S. beef exports. The F test at the bottom line of Table 3-5 is a join statistic test, and confirms that the fixed effects are non-zero. Finally, we re-estimated the model by dropping South Korea from the sample to check the robustness of our results. We found similar results in terms of sign of coefficients. These results are available upon request.

3.6.1. Impulse Response Functions

To scrutinize the effect of any shock from beef safety information on U.S. beef export, we estimate a model using panel vector autoregressive (Panel VAR) approach. The results of Impulse Response Functions (IRF) derived from the above mentioned model is reported in Figure 3-2.

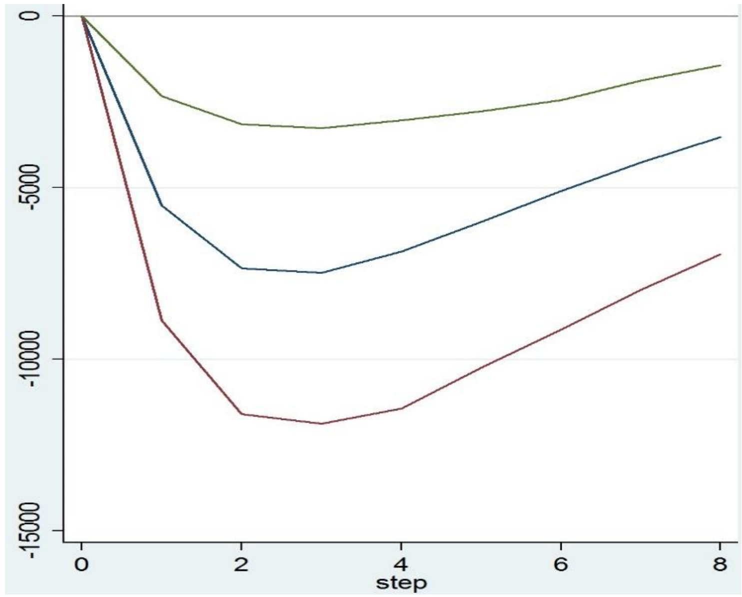

Figure 3-2- Response of U.S. Beef Export to a Shock from Beef Safety

Note: Upper and lower lines are 95% confidence interval.

The Y-axis represent the change in U.S. beef export.

Source: Research findings

Figure 3-2 shows that after a beef safety shock arising from publicized reports, the export level of U.S. beef will be affected adversely, and after several periods (quarters), this effect maximizes. Saghaian and Reed (2007) argue that as consumers learn more about the negative consequence of foodborne diseases over time, their reaction might be intensified to future outbreaks. As the consumers become more aware of safety incidents, more restrictions against the exporter country are applied, which results in less export. However, the effect of shock disappears over time and, the beef export markets will recover slowly. We can see in Figure 3-2 that it starts to rise after three quarters. A similar analysis for the Australian beef market shows that beef exports will recover over ten years to about 80% of its original value following a large outbreak (Buetre, *et al.*, 2013).

3.7. Concluding Remarks

This study contributed to the existent literature that generally looks at the effects of food safety incidents on the domestic or international demand for contaminated products. We constructed an index as a proxy for the consumer awareness of foodborne diseases. We utilized quarterly data in a gravity model for the four top U.S. beef importing countries, Japan, South Korea, Canada, and Mexico. We constructed an index of U.S. media reports of beef safety events to quantify the impact of beef safety information on the U.S. beef market, as the main objective of this study. It was concluded that each additional report about beef related foodborne disease led to a 0.8 % decrease in U.S. beef exports. In addition, using IRF, we visualized that the beef export decreased in response to beef safety news for three quarters, and then gradually increased.

This study has some practical implications for producers, exporters, and for the government. First, it is important to recognize the dynamics of consumers' reaction to a food safety news. When consumers receive a food safety news they generally over-react, and decrease their consumption abruptly, but gradually return to their past consumption pattern. We found the effect of a safety shock is intensified through the first three quarters. Supply chain managers can design an appropriate strategic response to consumers by learning this dynamic pattern. In addition, exporters can differentiate their products and gain official recognition by earning a disease-free status. Webb, Gibson, and Strutt (2017) discuss earning this status aid the exporter to restore the lost markets. However, it is costly and exporters must bear the costs of gaining this status. The length and extent of consumers' reaction must be taken into account to estimate these costs.

Second, despite the fact that the emergence of any kind of foodborne disease within a country is a threat to producers, they may consider this as an opportunity that could earn them more profits. Our results implicitly show beef safety information affects consumers' reaction. According to the discussion made by Saghaian and Reed (2007), consumers pay attention to origin and type of contaminated products. This argument has insights for meat companies and practitioners in the food industry who want to develop a strategic response to the consumers. They are encouraged to use beef safety as a quality and provide information about their food safety measurements proactively. Meat companies can take advantage using labeling and branding for their products. In addition, by investing in the tracking systems, the producers could address consumers' concerns about the origin of the products. These kinds of quality assurance measurements, not only create a niche market for quality-differentiated products, but also aid to restore consumers' confidence after food safety incidents. Hence, investing in any disease eradication program or traceability system that minimizes the impact of food safety shocks seems reasonable. Obtaining third-party certifications, such as ISO/IEC 17000:2004 is another example of the strategic response to food safety incidents. These certifications, which are funded by the private sector, serve to bring transparency to consumers, and provide market access opportunity for producers.

Third, there are some implications for governments' agencies and policy makers as well. Food safety incidents may destroy an entire export market for a period. After an outbreak, the exporters want to switch to a new market that is probably a lower value market but can offset the loss of missing the traditional markets. In this situation, it is of vital importance to be aware of the characteristics and values of international consumers and target markets. Being aware of international consumers' habits and needs smooths the path to access new markets. To grow U.S. beef exports to some new markets such as Indonesia and Egypt, investing in infrastructures to produce Halal beef is suggested. However, this is beyond the scope of this study and further research is encouraged to analyze the cost and benefit of this investment.

Finally, the food safety issues are not limited within a country. Hence, in the presence of a foodborne disease in a country, policymakers of the contaminated country are encouraged to cooperate with their trade partners to develop protocols and safety assurances. The harmonization of standards for food safety that addresses the concerns of diverse consumers in Asia, Middle East, and Africa is an example of this cooperation. International cooperation facilitates restoring public confidence and alleviates the economic burden related to the loss of export markets. The lack of bilateral cooperation, following an outbreak, would lead to longer economic losses for the countries involved.

The U.S. previous experience demonstrate that it might be impossible to restore consumer confidence after a disease outbreak without bilateral cooperation. Previous research (e.g., Peterson and Chen, 2005) revealed that one factor that adversely affected U.S. beef demand in Japan in 2002 was improper labeling of U.S. beef as domestic beef due to its similarity with Japanese dairy beef, such that both products were grain-fed. While Australian beef is grass-fed. Fox and Peterson (2002) state that the purpose of this mislabeling was to receive government subsidies. Japan's annual share of U.S. beef offal was 39% in the pre BSE-years but never surpassed 3% on average from 2004 to 2011 (Taha and Hahn, 2014). However, the U.S. benefited from reduced supply in Australia and New Zealand due to the drought, and regained market share from Australia after 2011 (USDA-FAS, 2017).

In summary, any foodborne disease is a double-edged sword. While many producers are subject to the risk of losing their market share, others may take advantage of appropriate strategic responses, which address consumers' concerns. As was shown, a number of studies indicate that consumers are willing to pay a higher price for safe food because they consider safe food having a higher quality. Therefore, the producers who proactively work to build credibility among consumers and gain their trust would benefit. Producers and exporters may use these recommendations to encounter situations where a foodborne disease occurs to prevent the consequent economic losses.

Chapter 4. U.S. Beef Cattle and Climate Change Mitigation

4.1. Introduction

Debates about climate change are one of the most political debates today (Rejesus, 2013). Climate change could lead to disasters such as more severe storms, rising average temperature, more intense rains or increased drought, and more forest fires (USDA, 2017). Researchers estimate that climate change has cost the United States more than $350 billion over the last decade (GAO, 2017).

The Agriculture sector accounts for about 22% of global total emission. This share is greater than that of the transportation sector. Within the agriculture sector, livestock production systems (including transport of livestock and feed) account for about 80% of total emissions (McMichael, *et al*., 2007).

Researchers believe that greenhouse gas emissions (GHG) from livestock are an emerging problem and can be discussed from several aspects. Beef and dairy are principal sources of GHG emissions amongst livestock products that account for 65% of total GHGs emitted by livestock (FAO, 2013). See Table 4-1.

In addition, livestock production contributes to deforestation and carbon dioxide (CO_2) emissions both directly and indirectly. Directly by animal grazing which results in degradation or cutting down the forests to provide more ranching space. Indirectly from increasing demand for animal feed which leads to the expansion of pasture through deforestation.

On the other hand, the increase in the world population will result in more food demand (Godber and Wall, 2014). It is predicted that consumption of meat and dairy products would increase by 76% and 65% respectively compared to a 2005-07 baseline (Bailey, Froggatt, and Wellesley, 2014), and livestock production is estimated to double by 2050 (Caro, *et al.*, 2017).

Table 4-1: Total Emissions from the Global Livestock Sector, by Main Animal Species

Animal Species	Equivalent CO_2 (Million Tonnes)	Share in Livestock Sector Emissions (%)
Beef Cattle	2495	35.30
Dairy Cattle	2128	30.11
Pigs	668	9.45
Buffalo	618	8.74
Chickens	612	8.65
Small Ruminants	474	6.70
Other Poultry	72	1.01
Total Emissions	7076	100

Sources: Research Calculation based on (Gerber, *et al.*, 2013) data.

Noticeably, the share of beef and dairy cattle is more than 65% of total livestock emissions. However, the results of Caro *et al.,* (2014) suggest that the beef cattle are responsible for 54% of total livestock emissions in 2010.

In general, Brazil, the United States, and China are the top emitters of livestock emissions in the world (Caro *et al.*, 2017). See Table 4-2. The United States is among the major meat-consuming and dairy-consuming countries. It is the third largest meat consumer after China and the European Union (EU), and the share of beef consumption among other red meats is considerable. The U.S. has the fourth rank in consuming milk and eggs, and is behind China, India, and the EU (Bailey, Froggatt, and Wellesley, 2014).

Table 4-2: Largest Emitter of Livestock Emissions in 2010

(Expressed as Equivalent CO_2)

Region	Equivalent CO_2 (Mt Co_2eq/y)	Share
Brazil	311	19%
United States of America	140	8%
China	129	8%
India	109	7%
Argentina	77	5%
Ethiopia	52	4%

Data Source: Adopted from Caro *et al.,* (2017)

Note: The numbers in the above tables refer to the total emission of livestock.

These six countries in the above table produced 50% of the global emission related to beef cattle in 2010.

To estimate emissions from beef cattle, following (Caro *et al.,* 2017) we take into account three emission sources, including enteric fermentation, manure management and manure left on pasture. Each of these sources is described blow.

4.1.1. Enteric Fermentation

The highest emission level of methane (CH_4) and nitrous oxide (N_2O) relates to livestock production. Enteric fermentation[8] is the largest source of CH_4. Manure and fertilizers applied in feed production are the biggest sources of N_2O (Bailey, *et al*., 2014).

CH_4 and N_2O emissions have a smaller share of global of global GHG emissions compared to CO_2 emission. However, their Global Warming Potential (GWP) is 21 and 310 times higher than CO_2. In other words, CH_4 and N_2O contribution to climate variations is 21 and 310 times more than CO_2 (Caro, *et al.*, 2017). For example, emissions of one tone of CH_4 have the same effect on climate change as the emission of 21 tons of CO_2 over a one-hundred year period. This serves to demonstrate how quantities of gases, such as CH_4 and N_2O, which seem negligible at first glance, actually contribute significantly to climate change.

4.1.2. Manure Management

Animal manure is consisted of water and organic material (Bouwman, 1996). Manure management is responsible for emission of both CH_4 and N_2O. The CH_4 production potential of manure is associated with the temperature and the way that manure is treated. (E.P.A., 2006). However, N_2O emissions are not associated with air temperature, and they are directly released from the nitrogen in animal waste as the result of nitrification and denitrification process (IPCC, 2006).

On the other hand, indirect N_2O are emitted from volatile nitrogen losses in the forms of ammonia (NH_3) and (NO_x)[9]. Nitrogen losses happen at animal production areas at the point of excretion, and continue through on-site management in storage and treatment systems (IPCC, 2006).

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[8]- Methane is emitted from the enteric fermentation, which is a digestive process in ruminant animals (Hook *et al.,* 2010).

[2]- NO_x is a generic term for the nitrogen oxides

4.1.3. Manure Left on Pasture

The third source of GHGs emissions are the manure which are left on pasture, and in other words are under no management system. N_2O is produced from this source directly and indirectly (Caro, *et al*., 2017). The direct N_2O emissions were explained before. Indirect N_2O emissions is related to nitrogen losses through runoff and leaching into soils from the solid storage of manure at outdoor areas, in feedlots and where animals are grazing in pastures (IPCC, 2006). Therefore we take it into account this emission source in this study.

However, we exclude emissions from the production of animal feed and forage, including nitrous oxide emissions associated with fertilizer application; land use changes; the transportation of animal feed, livestock, and food animal products; and emissions associated with imported food animal products. Considering all of the above mentioned sources is beyond the scope of this study. Appendix A, describes the equations for livestock emissions.

4.2. Literature Review

The impact of climate change on agriculture sector has been well-studied in the climate change literature (e.g., Mendelsohn, Nordhaus, and Shaw, 1994; Roesenzweig and Hillel, 1998; Adams *et al*., 1998; among many others). However, the contribution of agriculture and in particular the livestock sector to the Green House Gas (GHG) emissions has been largely neglected. Bailey, Froggatt, and Wellesley (2014) call livestock the forgotten sector in climate change studies, and discuss that the lack of knowledge among consumers regarding the contribution of the livestock sector to climate change hinder them to reduce their consumption of livestock products. Recently, there are several attempts to investigate this important issue though (e.g., Boer, Schösler, and Boersema, 2013; Hedenus, Wirsenius, and Johansson, 2014; Bajželj *et al*., 2014).

Caro, *et al.*, (2014) estimate the GHG emission from cattle production for the period 1961–2010 using IPCC guidelines. They found global GHG emitted from beef cattle have risen by 59% over the last five decades. They argue that beef cattle are responsible for 54% of total GHGs from livestock, while share of pork and chickens are 5% and 1%, respectively. They believe livestock emissions are mainly due to the dietary choices. As a solution for mitigating livestock emission, they suggest consumer to shift toward diets that cause less emission. It is while the current global trend is toward consumption of more cattle products.

In summary, the majority of existing research investigates the possible impact of climate change on agricultural production. In other words, they look at this issue from the producers' perspective.

The contribution of our study is to use the latest available data and estimate the emission levels for the period 1970-2014. The present study suggests an empirical model to quantify the impact of each mitigation option suggested by previous studies. Our hypothesis is that some activities such as, beefless Monday has a positive impact on climate change mitigation. This study has some policy implications for both supply side and demand side.

4.3. Model Specification and Estimation Techniques

This study has two objectives. First, we estimate the total GHG emissions from U.S. beef cattle. We are interested in examining the relationship between beef consumption and emission levels. To do that, we constructed a conceptual model based on the result of Hedenus, Wirsenius, and Johansson (2014) study. They discuss that there are three options for reducing GHG emissions from livestock sector, including productivity improvement, technical mitigation measurements, and human dietary changes. In order to quantify the effect of each suggested option over time we construct the below equation.

$$GHG_t = \beta_0 + \beta_1\, Cons_t + \beta_2 Prod_t + \beta_3 Tech_t + \varepsilon_t \tag{1}$$

The definition of each variable and the expected sign are presented in Table 4-3.

Table 4-3: Variables Applied in the Model

Variable name [a]	Definition	Expected sign
GHG_t	Total GHG emission associated with U.S. beef production (in log form)	Dependent variable
$Cons_t$	beef consumption	Positive
$Prod_t$	Productivity improvement of beef production that is measured by yield of product	Negative
$Tech_t$	The mitigation strategy that is measured as the amount of animal manure that leaches and volatilizes after applying on soil	Positive

All variables are measured over period 1970-2014

We should mention that there are several practical strategies to mitigate the GHG emission level. The purpose of all strategies is to reduce the emission level. Leaching and volatilization from manures contribute to the GHG emissions. Mitigation strategies, such as adjusted application timing of manure aim to avoid leaching, and volatilization losses (Van Es, Sogbedji, and Schindelbeck, 2006). However, since we are measuring the amount of manure which is leached and volatilized in our model, it has a direct (positive) effect on GHG emission associated with beef cattle.

To estimate the long-run relationship between the aforementioned variables, we need to check the existence of cointegration vector. Once the existence of cointegration is approved, in the next step we can estimate the associated error correction model as follow:

$$\Delta GHG_t = \alpha_0 + \sum_{j=1}^{p1} \alpha_1 \Delta GHG_{t-j} + \sum_{j=0}^{p2} \alpha_2 \Delta Cons_{t-j} + \sum_{j=0}^{p3} \alpha_3 \Delta Prod_{t-j} + \sum_{j=0}^{p4} \alpha_4 \Delta Tech_{t-j} + \phi ECT_{t-1} + \varepsilon_t \tag{2}$$

Where ECT is the error correction term, and its coefficient (ϕ) should have a negative sign. This coefficient indicates how quickly variables converge to longrun equilibrium

(Ozturk and Acaravci, 2011). To choose the lag length we can use some criteria, such as Schwarz Information Criteran (SIC) and Akaik Information Criteran (AIC). Koehler and Murphree (1988) have compared AIC and SIC in time-series analysis. The results of this comparison shows that it is preferable to apply SIC, which leads to lower order models for predicting. Therefore, this study used SIC as the lag length criterion.

4.4. Data

To collect data for emission levels of beef cattle we referred to the FAO database. FAO has released this data to the year 2014. This data has been available to the public and research community for the first time at June 2016. Also for productivity that is measured as the yield of beef cattle products, and the relevant data for technical mitigation we referred to FAO.

Data retrieved from USDA-ERS show that per capita consumption of beef (solid line) is decreasing while that of poultry (dashed line) is increasing over time (See Figure 4-1). It might suggest that beef consumption is substituted by poultry consumption over time (we did not use the consumption of poultry in our model, but for comparison purpose, we provide the data here). Table 4-4 presents the summary statistic of data.

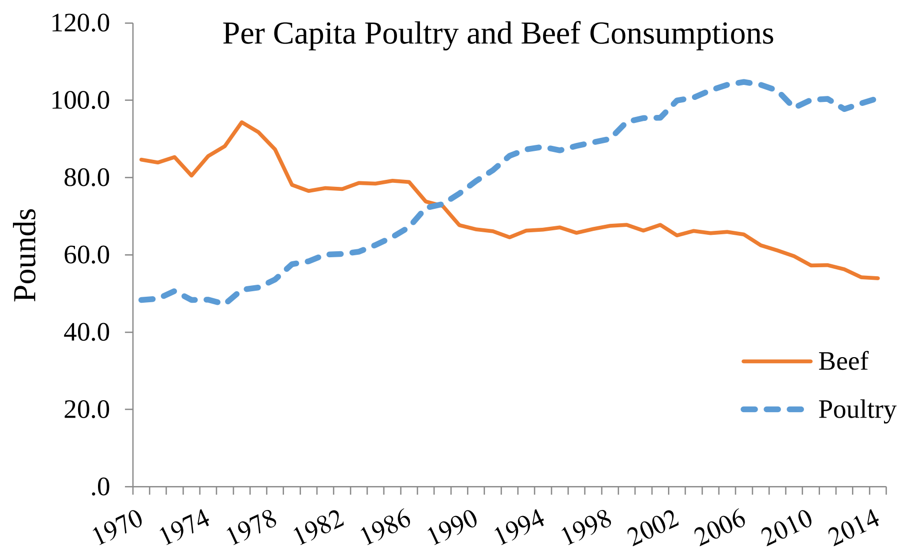


Figure 4-1: Per Capita Poultry and Beef Consumption in the U.S. from 1970 to 2014

Data Sources: USDA- ERS dataset

Table 4-4: Descriptive Statistics of Data (1970-2014)

Variables	Mean	Minimum	Maximum	Std.Dev.
GHG emissions (Million metric tonnes)	155.7	131.0	199.3	17.04
Productivity of beef production (Hg/An)	3009.5	2405	3712	357.22
Animal manure that leaches and volatilizes (Million metric tonnes)	0.234	0.197	0.299	0.02
Beef consumption (Per capita- Pounds)	71.3	54.0	94.3	10.29
Poultry consumption (Per capita- Pounds)	78.6	47.3	104.8	20.29

Source: Research calculations

Noticeably, the minimum value for both GHG emissions and the amount of manure that leaches or volatilizes occurred in 2014, and the maximum value for both variables was at 1975. In opposite, the minimum value for beef productivity was at 1975, and the maximum was at 2014.It would lead to the perception that any increase in production productivity has a positive impact on reducing GHG emissions. Also, any new technique to minimize the leaching of manure has a direct relationship with GHG emissions.

4.5. Results

Results of methane emissions from enteric fermentation process and manure management and total N_2O emissions from manure management are depicted in Figure 4-2. The trend in this graph is mainly associated with trend in beef cattle inventory. Results are expressed in terms of CO_2 equivalent, using the 100-year GWP measures.

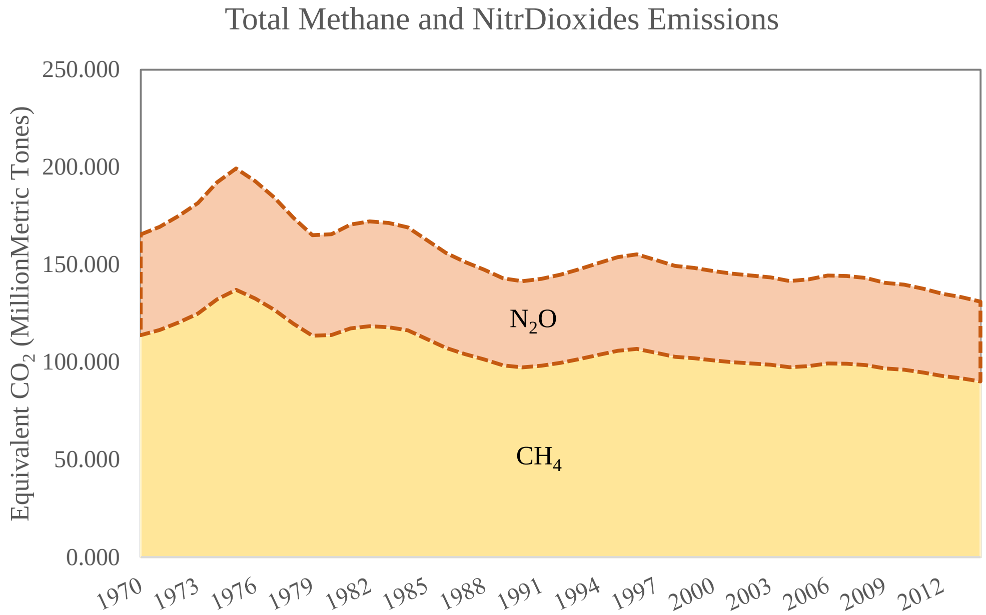


Figure 4-2: GHGs Emissions from U.S. Beef Cattle

Notes: Emissions are expressed in terms of CO2 equivalent and subdivided into methane (CH_4) and nitrous oxide (N_2O).

Nitrous oxide includes both direct and indirect emissions.

Sources: Research findings based on FAO data

As we can see in the above graph, CH_4 has the largest share in total emissions. CH_4 and N_2O have both a stable trend over time except for an increase around 1975. This increase and reduction after that are relevant to the total number of beef cattle.

The next graph, display the share of each source of emission in total GHG emissions (Sum of CH_4 and N_2O).

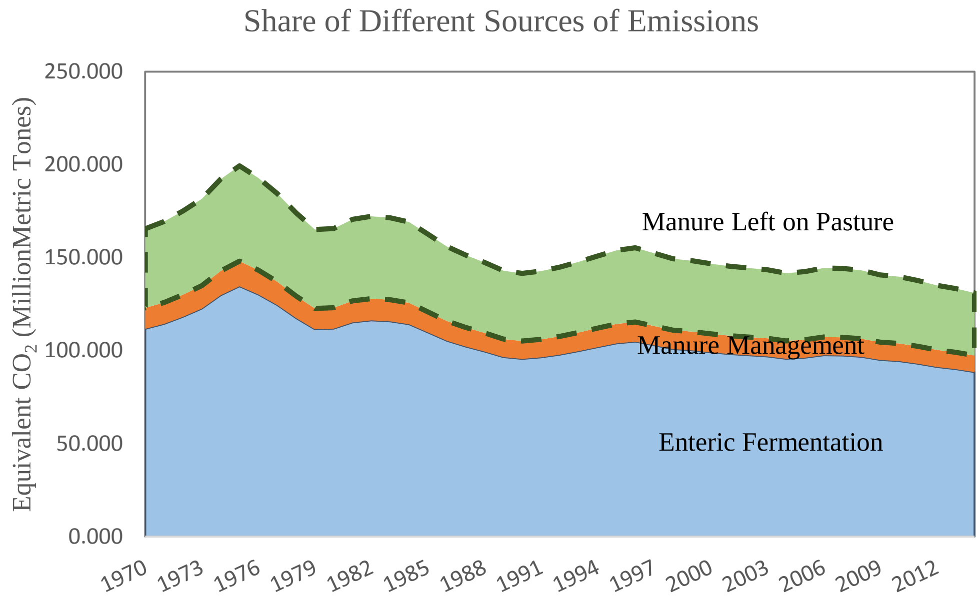


Figure 4-3: GHGs Emissions from U.S. Beef Cattle

Note: Emissions are expressed in terms of CO_2 equivalent and subdivided into enteric fermentation, manure management, and manure left on pasture.

Sources: Research findings based on FAO data

As we can see in the above graph, the largest area is related to the enteric fermentation process. This source of emission is mainly responsible for the total emission, and as we discussed earlier this source led to the emission of both CH4 and N2O. Afte that, manure left on pasture has the biggest share in emission. Finally, the smallest area is related to the share of manure management on total emission.

The result of the stationary test is reported in table 4-5. The results of the cointegration test and the error correction model are presented in Table 4-6 and 4-7.

Table 4-5: Results of stationary test (ADF)

Null Hypothesis: Variable has a unit root.

Test in	Level		First Difference	
Variable	T-statistics	Prob.	T-statistics	Prob.
GHG	-0.884	0.783	-4.408^{***}	0.001
Prod	0.124	0.964	-6.087^{***}	0.000
Tech	-2.686^{*}	0.085	4.551^{***}	0.000
Cons	-0.463	0.888	-5.460^{***}	0.000

Note: ***, **, * indicates significance level at 1%, 5% and 10% respectively.

Source: Research findings

The results of ADF test indicate that the null hypothesis of a unit root for all series is rejected at the first difference. Therefore, we can estimate the VECM model if the existence of a cointegration vector is approved.

Table 4-6: Johansen Cointegration Test Results

Unrestricted Cointegration Test Rank Result (Trace)

Null Hypothesis	Eigenvalue	Trace statistics	0.05 critical value	$Prob^{**}$
$R=0^{**}$	0.488	58.23	55.24	0.026
R<=1	0.355	29.36	35.01	0.0177
R<=2	0.127	10.49	18.39	0.0433

Note: R is the cointegration rank. ** indicates rejection of the hypothesis at the 5% leve.

Source: Research findings

The results reject the null hypothesis R=0 .This indicates that there is at least one vector of long-run relationships.

Table 4-7: Error Correction Representation

(Dependent variable is ΔGHG_t)

Regressors	Coefficients	Standard-Error	T-statistics
$\Delta Prod_t$	5.21E-07	1.1E-0.5	0.0048
$\Delta Tech_t$	3.16^{***}	0.211	14.93
$\Delta Cons_t$	0.0023^{***}	0.0006	3.814
Error Correction Term	-0.346	0.252	-1.36
$\Delta Constant$	-4.13		
R -Squared	0.81		
F-stat. F(5,38)	25.36		

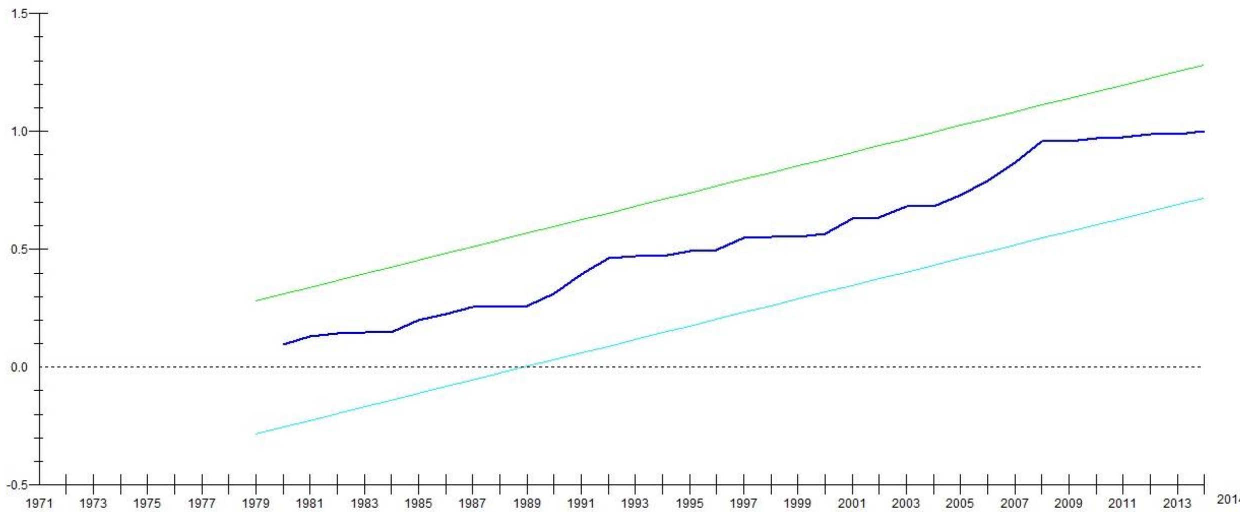
Note: ***, **, * indicate significant at 1%, 5%, and 10%, respectively.

Source: Research findings

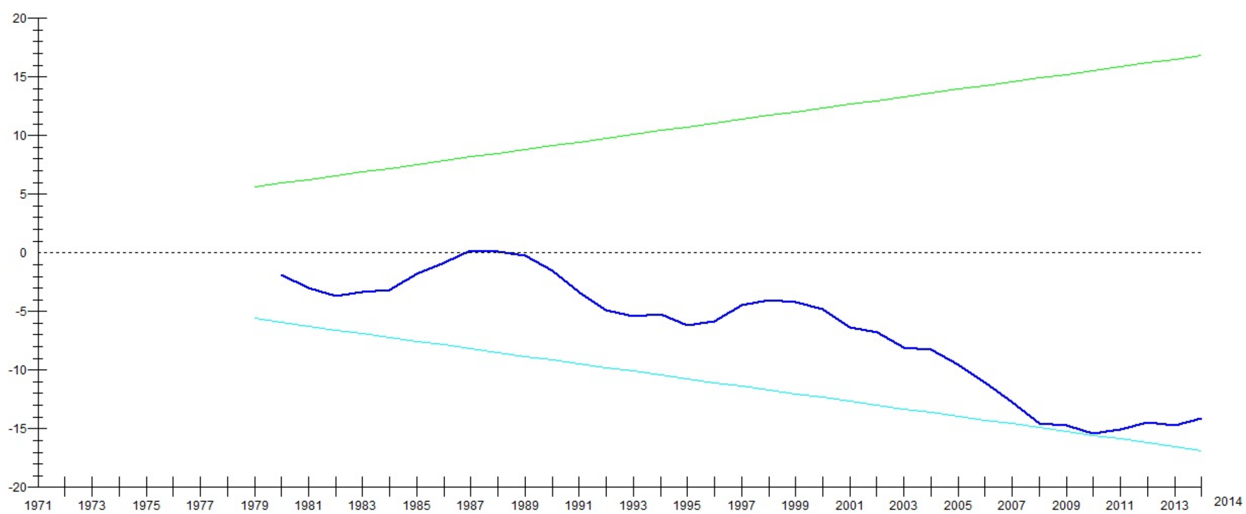
The results suggest that if all American consumers reduce their beef consumption, the associated GHG emissions from U.S. beef cattle would reduce by 0.0023 million metric tonnes annually. This suggests that changing consumption patterns do matter in mitigating GHG emission levels associate with beef cattle. However, this effect is small.

The coefficient for the productivity variable is not significant. One explanation for that is the fact that it is impossible to increase the productivity of beef production unlimitedly over time, and therefore we should focus on other mitigation solutions, such as technical strategies to reduce emissions. The variable for the technical mitigation has a positive and significant coefficient, meaning that if we could find some ways to reduce the leaching and vitalization of animal manure, then the GHG emissions would decrease. Otherwise, more leaching and volatilization from animal manure would result in more GHG emissions. The R^2 is 0.81, supporting that the model fits the data well. The computed F-statistics rejects the null hypothesis that all coefficients are equal zero. The absolute value of the Error Correction Term (ETC) indicates that 34 percent of the disequilibrium is offset by short-run adjustment in each year.

Finally, to examine the stability of the long-run coefficients and the short-run dynamics we employ the CUSUM and CUSUMQ test. These tests are respectively based on the cumulative sum of recursive residuals, and the squared recursive residuals of the model (Bahmani-Oskooee and Ng, (2002)). Figure 4-4 displays a graphical representation of the above mentioned test. As can be seen, none of two plots cross the critical bounds that affirmed the stability of long-run coefficients. In other words, the null hypothesis that all coefficients in the error correction model are stable cannot be rejected.



a- Plots of CUSUM Statistics for Coefficient Stability



b- Plots of CUSUMSQ Statistics for Coefficient Stability

Figure 4-4: Plots of CUSUM statistics for coefficient stability (a), and Plots of CUSUMSQ statistics for coefficient stability (b)

Note: The straight lines represent crotical bounds at 5% significance level

Source: Research findings

4.6. Conclusion

This article contributes to the existing literature on climate and quantifies the GHG emissions from beef cattle production. In particular, this study has confirmed that reducing beef consumption by American consumers would reduce the GHG emissions. In addition to the expected signs obtained from the model, the estimation results suggest that changing consumption patterns do matter in mitigating GHG emission levels associate with beef cattle.

On the supply side, some actions have been recommended by researchers. For example, methane abatement strategies, timing manure application, or modifying dietary combination for cattle that led to less emission (Lupis, *et al.*, 2012). These strategies are discussed in previous studies (e.g., Hook, *et al*., 2010).

We used Tire 1 method calculations in this study. As Caro, et al., (2014) argue, this method does not provide information about livestock production efficiency over time. However, it indicates how GHG emission associated with livestock production has occurred. This method will provide the basic information for establishing policies to mitigate climate change. We encourage to use Tire 2 method in future studies. It is also recommended to see the impact of changing geographical locations of cattle farm to the regions that have lower emission factors in future studies. Because air temperature is a factor that affects the emission from livestock manure.

In summary, apart from the need to practice appropriate mitigation techniques on the supply side, and to promote the productivity of livestock production, the authorities should also take steps to magnify the importance of consumption side actions. For example, by providing information to the public that encourages people to consume more environmentally friendly diets such as vegetarian, and flexitarian[10]. Media attention is needed to convey this message to the public that eating more meat is environmentally detrimental, and we need to change our diet to confine GHG emissions.

10- Flexitarian consume meat only several days per week (Dagevos and Voordouw, 2013).

Appendix A. GHG Emissions Equations Based on IPCC (2006) Guideline

To estimate emissions from U.S. beef cattle, we followed IPCC guideline. Equation (1) and (2) represent the released methane from enteric fermentation and manure management, respectively.

$$Methane_{fermentation(t)} = EF_{fermentation} \times N_t \times 10^{-6} \qquad \text{Equ (1)}$$

Where:

$Methane_{fermentation(t)}$= methane emissions from enteric fermentation at time t, (Gg CH_4 yr^{-1})

$EF_{fermentation}$ = emission factor for beef cattle in North America region, constant over time, (Kg CH_4 $head^{-1} yr^{-1}$)

$N_{(t)}$ = the number of beef cattle at time t (head)

$$Methane_{manure(t)} = EF_{manure} \times N_t \times 10^{-6} \qquad \text{Equ (2)}$$

Where:

$Methane_{manure(t)}$= methane emissions from manure management, for a defined population, (Gg CH_4 yr^{-1})

$EF_{manure\ (t)}$= emission factor for beef cattle at time t, (varying by annual temperature) (Kg CH_4 $head^{-1} yr^{-1}$)

$N_{(t)}$ = the number of beef cattle at time t (head)

After estimating equation (1) and (2), we multiply the results by global warming potential of CH_4 and N_2O (GWP) to have carbon dioxide equivalent (CO_2 eq). As we discussed earlier, the dry lot and on-pasture manure management are two management systems relevant to beef cattle in North America (IPCC, 2006).

To estimate the direct and indirect nitrogen oxide associated with manure management, we use equation (3) and (4), respectively. These equations are based on IPCC guideline.

$$N_2O_{D(t)} = \sum_{s} \left[N_{(t)} \times Nex_{(t)} \times MS_{(s,t)} \times EF_{3(s)} \right] \times \frac{44}{28}$$

Equ (3)

Where:

$N_2O_{D(t)}$ = direct N_2O emissions from Manure Management at time t, (Kg $\mathrm{N_2O\ yr^{-1}}$)

$N_{(t)}$ = the number of beef cattle at time t (head)

$Nex_{(t)}$= annual average N excretion per head at time t, (Kg N $\mathrm{animal^{-1}yr^{-1}}$)

$MS_{(t)}$ = fraction of total annual nitrogen excretion for beef cattle that is managed in manure management system *dry lot*, dimensionless

EF_3= emission factor for direct N_2O emissions from manure management system *dry lot*, constant over time

And

$$N_2O_{ID(t)} = \sum_{s}\left[NE_{(t)} \times Frac_{GasMS(s,t)} \times EF_4\right] \times \frac{44}{28}$$

Equ (4)

Where:

$N_2O_{ID(t)}$ = indirect N_2O emissions due to volatilization of N from Manure Management at time t, (Kg $\mathrm{N_2O\ yr^{-1}}$)

$NE_{(t)}$ = total nitrogen excretion from manure management

$Frac_{GasMS(s,t)}$= fraction of managed manure nitrogen that volatilizes as NH_3O and NO_x in the manure management system S, %

EF_4= emission factor for N_2O emissions from atmospheric deposition of nitrogen on soils and water surfaces, constant over time

In the above equation the variable $NE_{(t)}$ is calculated by multiplying the variables $N_{(t)}$, $Nex_{(t)}$, and $MS_{(s,t)}$ that were explained in equation (3).

For complete coverage of the direct and indirect N_2O emissions and accurate estimation we need to estimate emissions for all anthropogenic inputs and activities (IPCC, 2006). Figure (A-1) summarize the calculation steps schematically as follows:

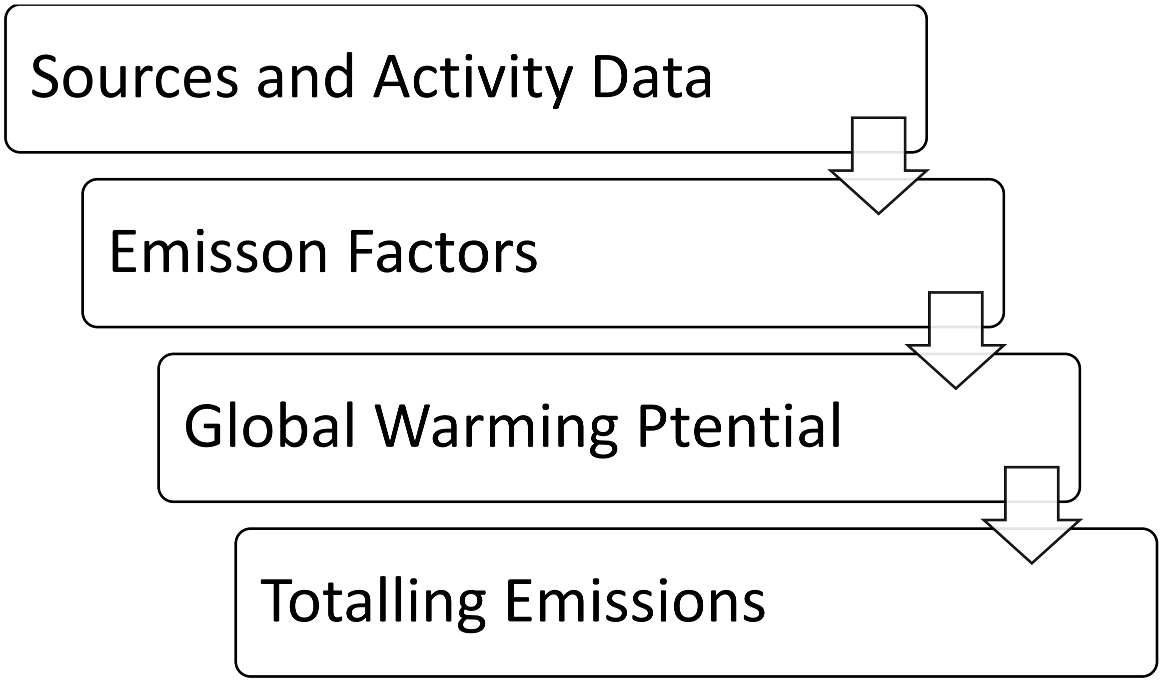


Figure A-1: Schematic View of Calculating GHG Emissions

Sources: Based on IPCC (2006) guideline

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Vita

Education

- MSc, Agricultural Economics, Tarbiat Modares University, Tehran, Iran, 1/2012
- BSc, Agricultural Economics, University of Tehran, Tehran, Iran, 8/2009

Academic Appointments

- Primary Instructor in AEC 300 (Information Literacy for Agricultural Economics). University of Kentucky, Spring 2017
- Teaching Assistant in AEC 309 (International Agricultural Food Needs). University of Kentucky, Fall 2016
- Research assistant, Department of Agricultural Economics, University of Kentucky 8/2013 – 12/2017

Scholastic Honors

- Passing the Torch Student Awards, University of Kentucky, October, 2016
- First place poster presentation in *Intercultural Awareness Day* meeting, October 2015, University of Kentucky, (Title of poster: Price Transmission Analysis for Nicaragua Rice Market).